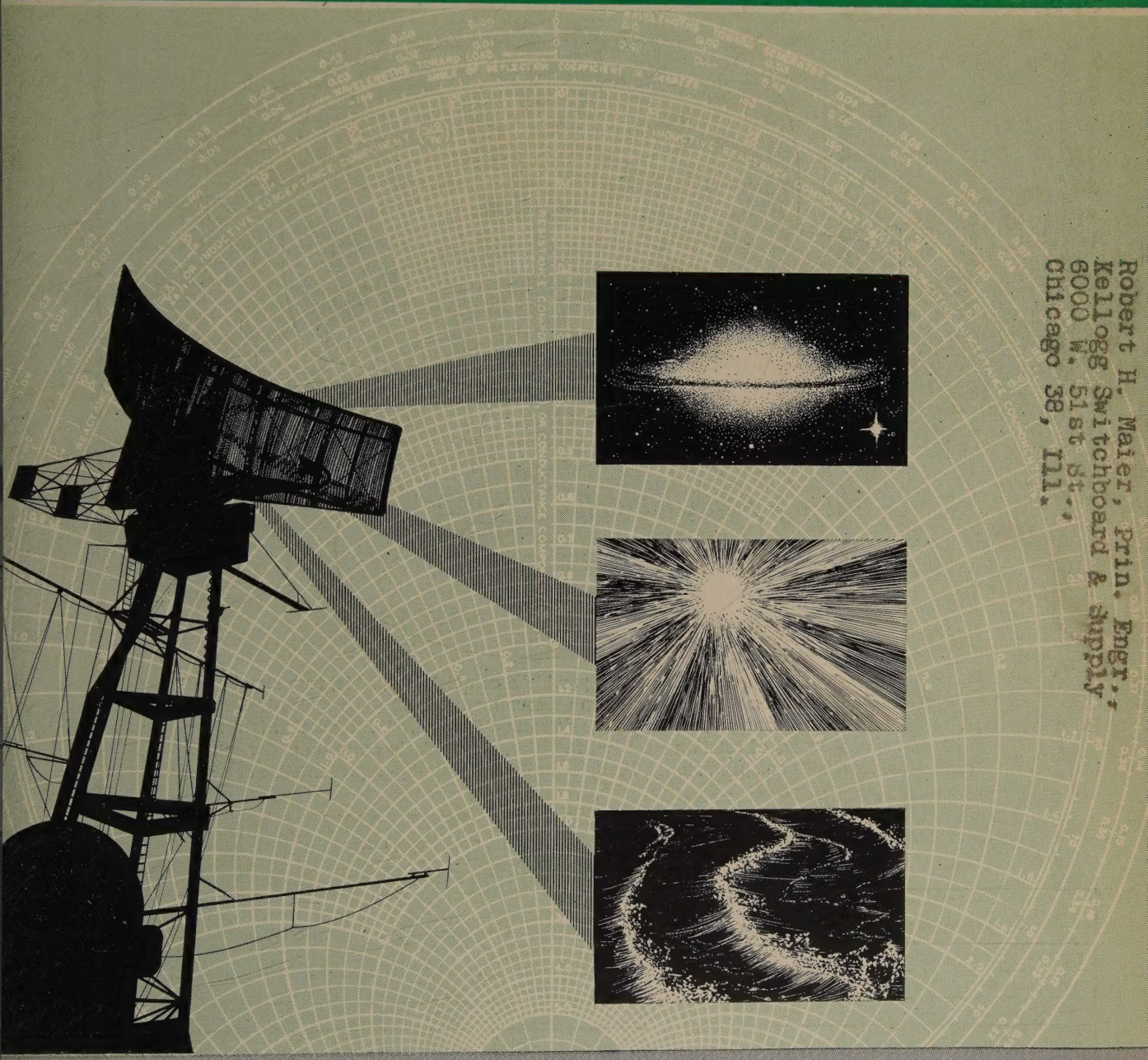
JUNE 1959
VOL. 2 • NO. 6

- Hansen — Low Noise Antennas
- Southworth — Graphical Analysis of Microwave Components, Part I
- Mohr — Rapid Measurement of Microwave Cavity Parameters

the microwave journal



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standard of measuring speed and accuracy

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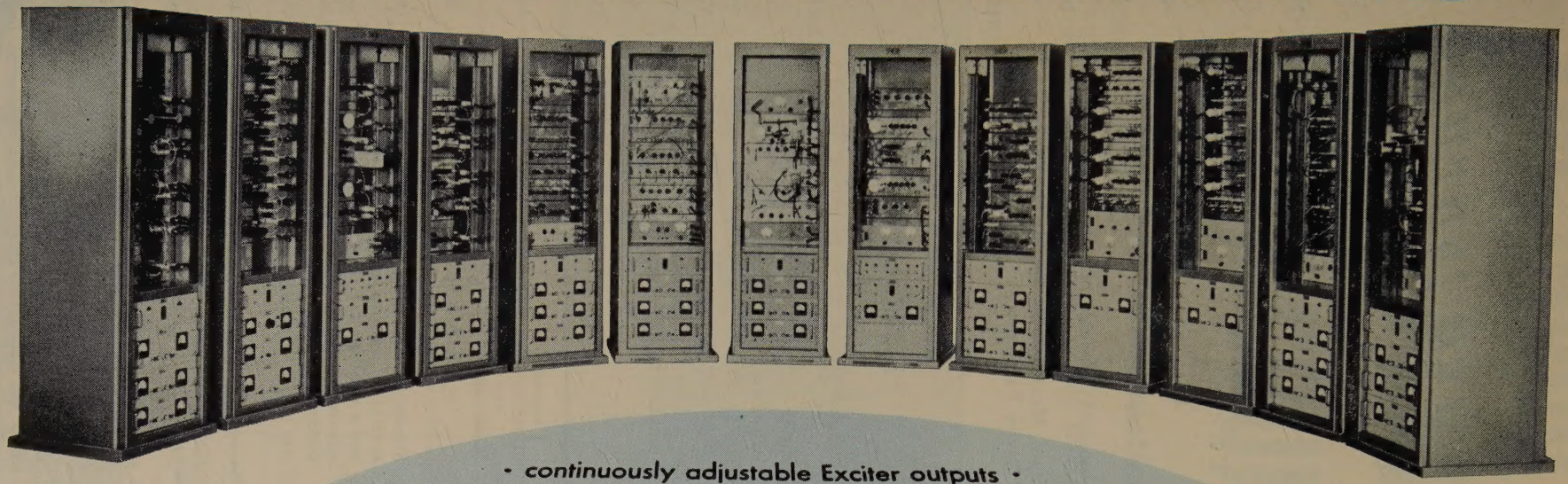

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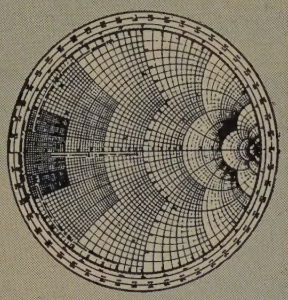

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COVER DRAWING

(Courtesy of Microwave Lab., Hughes Aircraft Co.)

Shown in the artist's drawing are three sources of antenna noise: sea, the sun, and a spiral galaxy. How these determine antenna noise temperature is described starting on page 19.

Art by R. W. Bradley and E. Minishian.

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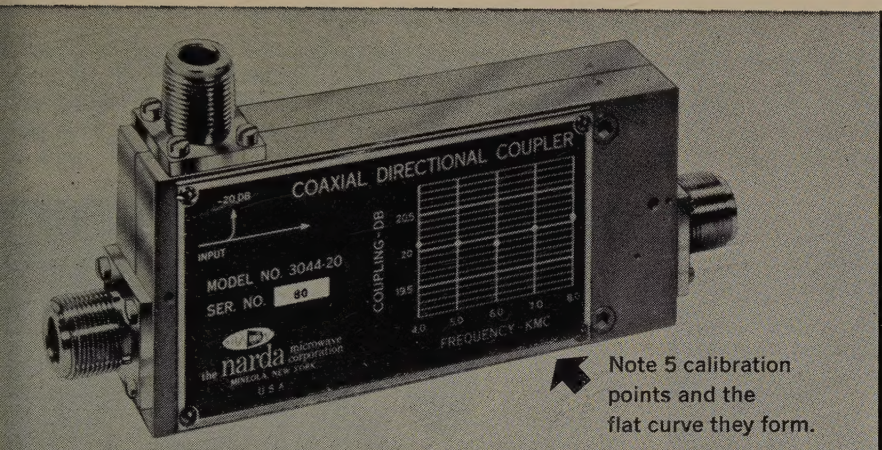

Note 5 calibration points and the flat curve they form.

Coupling Characteristics

Frequency Response	±0.2 db
Deviation of Mean Value from Nominal	±0.3 db
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Calibration points at 5 frequencies

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Frequency (mc)	Nominal Coupling	NARDA Model	VSWR Primary, VSWR Secondary	Minimum Directivity (db)	FORWARD (watts)	Power Rating REV. (watts)	PK. (kw)	Price
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00-1000	20	3041-20	1.1/1.2	20	1000	100	10	
50-2000	20	3042-20	1.1/1.2	20	1000	100	10	
00-4000	20	3042-20	1.15/1.2	20	1000	200	10	
00-8000	20	3044-20	1.2/1.25	17	1000	200	10	
00-11,000	20	3045-20	1.25/1.3	15	1000	200	10	

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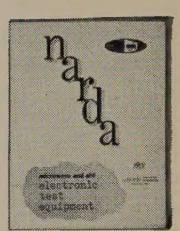

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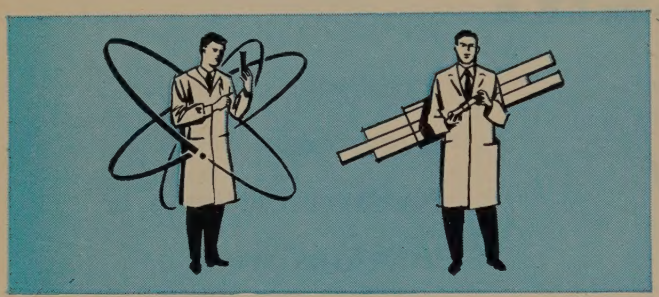

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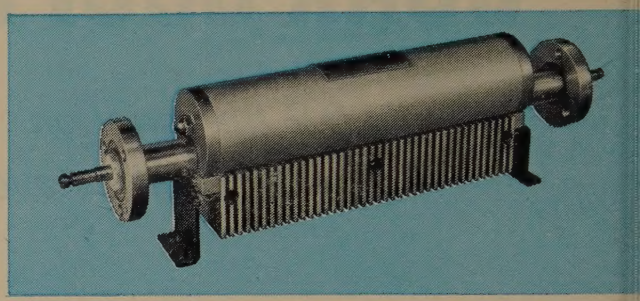

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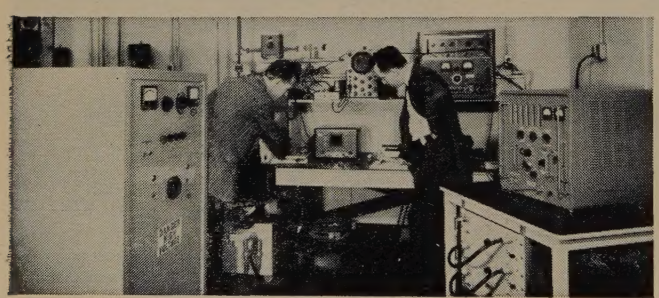

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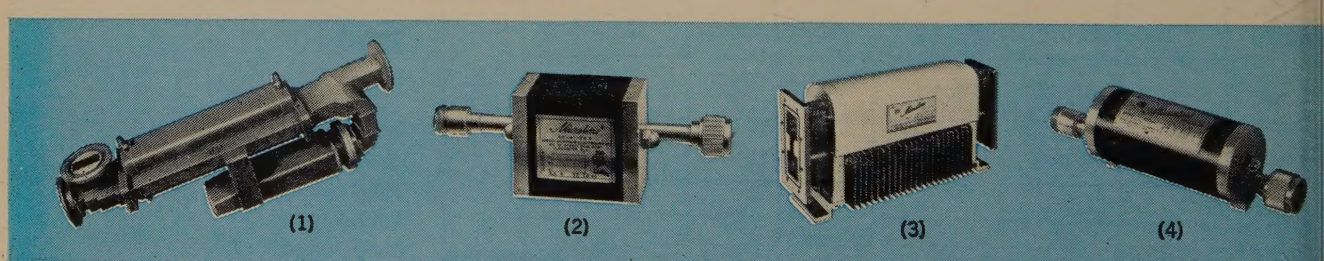

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CIRCLE READER SERVICE CARD 2

The February issue of Microwave Journal carried an article by Mr. Herbert Finke, General Manager of Polytechnic Research and Development Co., Inc., entitled "The Conservation of Engineering Talent." In this article Mr. Finke uncovered a serious problem in the engineering industry, — the "flight into management" by top technical talent, because of dissatisfaction with salary and prestige levels. The deleterious effect of such an exodus was examined in detail, with a view toward effecting an intelligent solution.

Reader reaction indicated that Mr. Finke had accurately stated a condition which has needed open discussion for a long time. Following is a further exploration of this industry dilemma in question and answer form.

HE CONSERVATION OF NGINEERING TALENT

(Part 2)

Herbert A. Finke

Q. In your February article you pointed up the misuse engineering talent with the "upgrading" of the most outnding technical people into administrative slots, alough, often, they are ill-equipped for management funcns. How did this come about?

A. The growth of the entire engineering industry thin the last fifteen years has been phenomenal. A strikg example of this is the microwave field which is, perps, most familiar to the readers of this magazine. When D was organized, in 1945, we were the only company signing and manufacturing precision microwave test uipment. Today there are many in the field. As technological advances were generated the proficiency of engiers increased and companies grew and prospered. Larger mpanies, plus an increased number of companies, opened w vistas in administrative and sales positions, which atcted top engineering talent seeking personal fulfillment. e salaries are larger and the social prestige is greater management than in technical engineering. It is untunate that responsible leaders of the industry did not lize that superior technical engineers embody the élan cessary for progress, only when they choose to remain suior technical engineers! If compensation and recogni- were accorded technical personnel to the same degree that accorded administrative personnel, the problem misuse of technical talent might not have assumed the lignant characteristics evidenced at the present time.

Q. Assuming that a company's top engineering talent lso capable in the management field, do you think they uld be confined to the technical end of the business?

A. I do not advocate the freezing of engineers to their ches by a masterful "Übermensch" managerial class. e Nietzschean philosophy is repugnant to the American cept of freedom of individual initiative. Unquestion- technical management must evolve from the ranks of erienced, qualified engineers. Some engineers will ve to be endowed with the judgment, personality and ability requisite for sound administration. As their eers mature they will evolve as managers, replacing who have moved on and filling newly created posis due to industry growth. The inexorable mortality of , coupled with the assertive force of a strong new eration, is a universal determinant.

Technical talent, however, must be nurtured with every resource at our command because it is the cornerstone of the engineering profession. The development of finer products, which will obsolete existing ones, and new products, to satisfy new requirements, is fundamental to the continuing vitality of our industry. It is the creative spark of the research scientist, and the intelligent channeling of his ideas, that we squander, in failing to perceive that salary and status must be suitably equated to cultivate the natural bent of the individual.

Q. But why should top engineers be used to solve technical details? Wouldn't the setting of direction be sufficient?

A. The establishment of a broad direction is an important initial step in every program, but a long, long way from safe harbor. The variety and magnitude of technical "details" require the highest degree of ability right on the job. The solution to the whole problem is a function of the optimum solution of each detail.

Q. Why can't individual companies work out their own problems by raising the salaries of top technical people?

A. We have tried to do this at PRD but it appears to solve only half the problem. Remaining unanswered is the powerful force of social prestige and recognition.

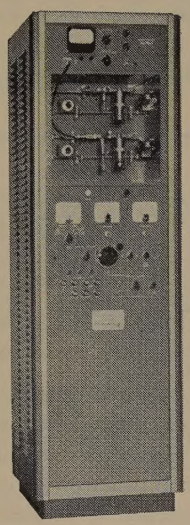
Right now, to the public at large, the "engineer" can be a most assiduously trained research scientist or a laboratory technician. Many people misrepresent themselves as "engineers" to their social world although they are working at relatively low-level jobs. Inevitably the inflated use of the term has chipped away at the value of the genuine article. How can we expect the man who has spent many years in engineering training to take pride in the working level of his profession? He is obliged to rush into an executive haven to satisfy his desire for prestige.

If we do nothing else, it will be a major step to accurately determine the requirements for the use of the title "engineer." Consider what a man must accomplish before he can assume the title of doctor, dentist, lawyer, certified public accountant, etc. He must take a prescribed course of instruction, at a recognized professional school, and be

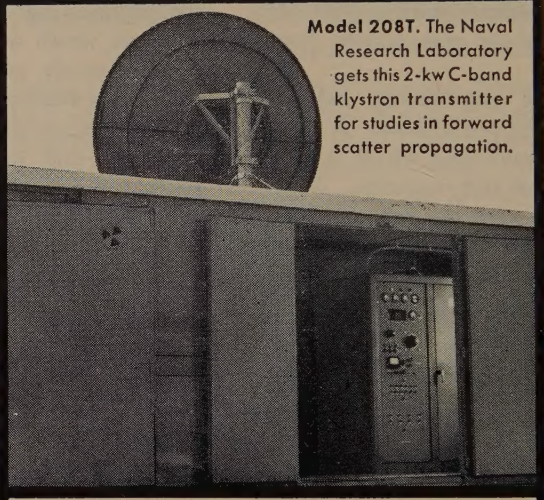
(*Continued on page 7*)

WORK IN PROGRESS AT LEVINTHAL

Among the various projects on the work docket in the Levinthal Stanford Industrial Park plant, these samples give a hint of the breadth of capabilities existing here.

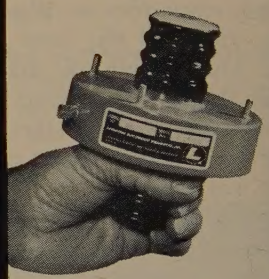


Model 99P. An 18- to 40-kmc 1-mw signal source for Douglas Aircraft Company. Designed for counter measures, this instrument also serves as a general-purpose laboratory device.



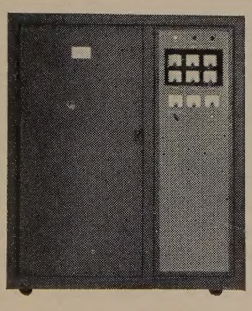
Model 208T. The Naval Research Laboratory gets this 2-kw C-band klystron transmitter for studies in forward scatter propagation.

Model 240T. A 17-mc transmitter for propagation research, this unit provides 400 kw of peak power. User is the University of Alaska.



Pulse-Current Transformers. One of the more standardized product lines in the Levinthal Pulse-Transformer Department, these units are designed for monitoring cathode currents of klystrons, magnetrons, amplitrons, or twt's.

1Q1, 75-kv, 150-amp pulse, $275.
1Q2, 150-kv, 150-amp pulse, $348.
1Q3, 250-kv, 200-amp pulse, $402.



Model 224M. This is a 20-kw 200-mc pulse power amplifier for Brookhaven National Laboratory. It will serve as part of an r-f driver chain for a linear accelerator.

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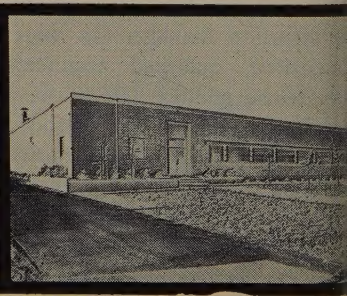

onservation of Engineering Talent

(*Continued from page 5*)

varded a degree. He must serve an apprentice period to ain "on the job" experience. He must pass one or more xaminations to determine his fitness to pursue his chosen eld of work. A man, who has successfully attained his rtification, has an ethical right to protect his professional eld from people who assume the title without having met e qualifications.

In order to call himself an "engineer" a man should have degree from a recognized engineering school and be mployed in an engineering capacity — not as a mechanic, epairman, draftsman, etc. The electrical engineer, the icrowave engineer, the communications engineer, should e meaningful distinctions based on educational qualifi-ations, job experience and — perhaps — carefully con-eived oral and written examinations.

We can profit by an inquiry into the activities of other rofessional societies, such as the American Medical As-ociation and the Bar Association. They play a key role n guarding and promoting the socio-economic interests of heir members and upholding the standards of the pro-ession.

Q. Do you see any solution to the total problem?

A. The real starting point is to have the technically ac-ve engineer recognized as the truly important individual e is.

The renaissance of his prestige is a fundamental re-ponsibility of the engineering schools and the dominant echnical engineering societies. It is up to the schools o set the standards of excellence, and it is up to the pro-essional organizations to uphold them.

The pre-eminent professional engineering societies have voided participation in the socio-economic affairs of their nembers. In my opinion, they cannot maintain their itality by continuing to pursue this neutralist course. Al-hough the most illustrious members of the profession may ot require such assistance, it is evident that the younger ngineers do.

Q. I believe many people will disapprove of such a course. Don't you?

A. To the dedicated core of men who started their careers when the engineering world was a small one, and economic conditions were different, these new problems may, in truth, be distasteful and unworthy of the profession to which they have devoted their energies. These men, however, who are the leaders of the industry today, can be relied upon to act in the interests of the profession, as times change and the problems of our rapid and enormous growth become critical.

There is a huge job to be done and, by employing the "collective genius" of all the professional societies, the job can be done! Technical societies, such as IRE, ASME, AIEE, etc., could, with dignity, present the accomplishments of the engineer to the lay public. People are wont to accept our end products as a mechanical matter-of-course, without realizing the training, ingenuity and tenacity that made the product possible.

Our progress in the international scientific struggle should be presented by men of great stature in our industry, whose individual achievements merit public acclaim. Men of this caliber can do much to enhance the reputation of all engineers, because they command an audience, and can highlight the essential contribution of supporting engineering groups to all major scientific advances.

I believe that the professional societies should establish active committees to study this problem, and then carry out an extensive public relations program for the benefit of the entire industry. Is it not just, and proper, to present our story through the very media of communication we have made possible?

To those who have recognized this problem, and who agree that action is necessary, may I point out that you — as a member of a professional society — can indicate your interest. The collective "you" should write to your societies, and give other interested members an opportunity to be exposed to your thinking. The goal of your group effort, this time, is a personally precious one — the protection and enhancement of your individual career prestige.

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INDUSTRY NEWS . . .

RAYTHEON GROUP TRANSFER

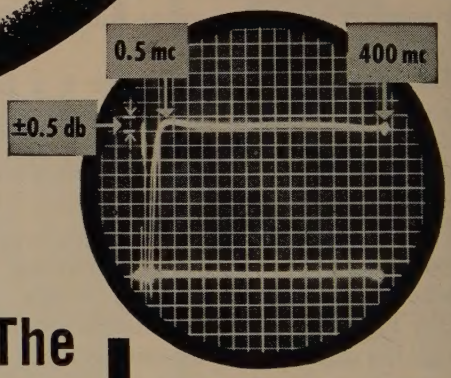
In a move it says will provide better service for its industrial customers as well as the armed services, Raytheon Company has transferred its Special Microwave Device Group to the company's Industrial Apparatus Division. An integrated business with its own research, development, production, and sales staffs, the group started in the Research Division where it had been assigned while its products and techniques were being developed and were gaining acceptance.

The Special Microwave Device Group creates isolators, duplexers, phase changers, circulators, amplitude modulators, switches, and other devices. These products are finding increasingly important applications in radar and communications systems where they are used to control microwave energy.

Dr. Howard Scharfman heads the group which is expected to number 75 by year's end. Basing projections on continued growth in present product areas without considering possible new additions to the line, Dr. Scharfman expects the group to grow to at least 125 by the end of next year and to double that by the end of 1963.

• • •

(*Continued on page 12*)



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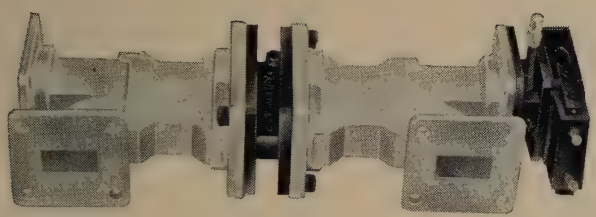
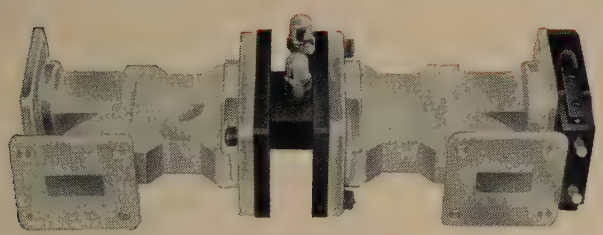
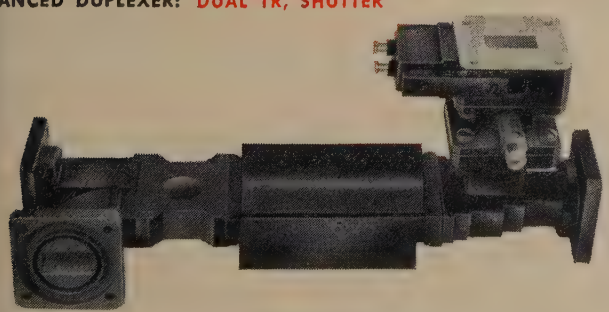


ALANCED DUPLEXER: DUAL PRE-TR, DIODE PROTECTOR, SHUTTER



ALANCED DUPLEXER: DUAL TR, SHUTTER



RRITE DUPLEXER: DIODE PROTECTOR, SHUTTER

New Microwave Associates Ku Band duplexers give you guaranteed crystal protection – for life – at full rated power and elevated temperatures.

For the first time, Ku Band users are enjoying crystal protection never before attained in this band!

New, highly successful gas tube and ferrite devices of proven design but previously produced for L, S & X bands, are now in actual production for Ku Band . . . and available for immediate delivery.

These new duplexers developed by Microwave's Switching Devices Laboratory under the direction of Dr. Lawrence Gould are guaranteed to solve premature crystal burnout problems. One of these systems will bring you optimum duplexer performance and reliability. All three use the MA-760 shutter for standby receiver protection.

If you work with the Ku Band, you owe it to yourself to see how these latest developments from Microwave will bring you new concepts in receiver performance and crystal protection. Write or call our application engineering department.

MICROWAVE ASSOCIATES, INC.

BURLINGTON, MASS. TEL. BRowning 2-3000

FROM THE EDITOR

One of our readers has brought to our attention the possibility of rendering a greater service through our New Products Columns.

It was his opinion that the New Products feature in technical magazines is somewhat abused. He felt that some better control on the part of the editorial board of "the microwave journal" would be of great value to the industry.

He pointed out some of the abuses with particular emphasis on two specific areas. The first abuse has to do with a tendency on the part of some companies to use New Product announcements for market surveys. Usually a company will have an idea that a given product can be built with certain specifications. They then make a premature announcement of it in their New Product Release. They hope that the reader reaction will give them an indication as to the potential market of their product.

The second abuse is related to the first; except that in this case a unit has actually been hand produced, but the company is not properly tooled up for delivering any units within a reasonable length of time (i.e. 90 days). Here again, the reader is misled into believing the unit is a stock item readily available.

The danger of a policy of this type is obvious. The engineer who plans a program with devices seen in the New Products Column in mind falls into an unfortunate trap and the company making the announcement suffers by failing its potential customer.

Our interested reader, a man of stature in the industry, offered a possible solution to the problem. He felt that strict control of New Product releases was advisable. He suggested that all new product releases be accompanied by a certificate of performance to indicate that working units actually met the operating specifications listed. He also suggested that no product be allowed to appear unless it is deliverable within a reasonable length of time.

The problem is more complicated than indicated here, and a reasonable solution must be palatable to all concerned. The New Products department of this or any other magazine constitutes a service to all. The manufacturer uses it to showcase his latest products; the engineer uses it to do his window shopping.

We agree that something should be done to protect the proper use of this feature. If you have any thoughts on the matter, we would appreciate your suggestions or comments.

The July issue of the journal will feature in its technical section the following papers — Spin Waves by Dr. P. E. Tannenwald; Modulator Techniques for Gridded Klystrons and Traveling-Wave Tubes by J. P. Swanson; and Part II of Graphical Analysis of Waveguide Components by Dr. Southworth.

Theodore S. Saad

CORRECTION —

In Tore Anderson's "Directional Coupler Design Nomograms" which appeared in the May 1959 issue, the following corrections should be applied: Along the horizontal axis of the charts on pages 35 and 36, the numerals should be preceded by decimal points. On Page 36 the thickness dimension "t" should appear for the broad wall of the waveguide; and the ratio L/A should be applied to the horizontal axis.

Letters to the Editor

The Editor
the microwave journal

Dear Sir:

In the middle 30's in a talk giv by Slepian before an AIEE or IR meeting, in New York City, I heard method of distinguishing betwe mathematicians, scientists and eng neers which is more brief and possib more elegant than that offered by M Pease in your April issue. The distin tion between them is based not o their training nor on the work th perform, but solely on their purpos I am paraphrasing Mr. Slepian's stat ment as I remember it. A mathem tician is one who is interested in i vestigating self-consistent possib worlds without regard to whether an of these corresponds to the wor around him. A scientist wants to di cover as much as he can about th world in which we exist without r gard to the utility of the informatio An engineer is interested in produ ing effects useful to people. All o them operate at a professional, no routine level.

This is the most easily applied s of distinctions that I have ever hear Of course, by these definitions the are only a few scientists and eve fewer mathematicians. Many of tho who consider themselves mathemati ians and scientists would be classe as engineers by the foregoing rule Obviously, these rules have not bee accepted generally.

Very truly yours,
Israel Rotkin
Diamond Ordnance Fuze Lab
Washington, D.C.

» • «

Dear Mr. Rotkin:

Your interesting letter to the Edito of *the microwave journal* was fo warded to me. I did not hear the ta by Slepian to which you refer. Th definitions you quote are, as you sa quite brief and elegant. Had I bee aware of them, I might have use them.

Your statement that these defin tions are easily applied, I protest. Th point of my editorial is that no de nition is easy to apply — at least those who have to apply it objectivel You apparently agree since you s that the distinction is not based o their training or the work they do. is entirely internal — one of attitud

ıd therefore exceedingly difficult to dge from the outside. But I main-n that it is still a vital distinction; at a manager, for example, must cognize into which category the ople under him fall. If he does not, en there will be trouble, and often ious trouble. But how is a manager read with precision the basic pur-se or drive of the individual he must egorize?

As you point out in your last para-aph, there is a further complication this in that the individual may ry well misjudge himself — that entimes he is not, in fact, what he nsiders himself. Therefore, it is not fficient for the outsider — manager whoever — to take the individual's vn judgment. Not if he wants the o done in a manner consistent with s own purpose.

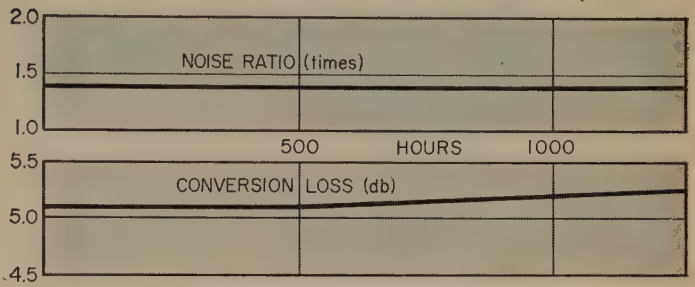
There is one quarrel I have with ese definitions — and with those I ed as well. They suffer from the fect that is in so many of the words d phrases that are used to discuss otivations. They imply, if they do t state, constancy — that a man is e and not another. I do not think example, that a man can be a good eoretical engineer, and therefore in-ested in utility, without also having me interest in both the "real" world d in possible worlds. And I also nk that there will be times when e or the other of these other inter-s will be dominant, so that he is t at that time acting or thinking as engineer. Likewise no mathema-ian, no matter how "pure" or ab-act, is completely devoid of interest usefulness. Utility, in this case, y be with respect to other mathe-ticians rather than to the lay pub-but it is still there. You cannot, er all, talk about utility in the ab-act. It requires a reference point of neone to whom it is, or is not, to be ful.

But this latter is a separate subject l beside the point here. If, as I nk we agree, the distinction be-een mathematician, scientist, and gineer is a significant one, then one st have some definition, even if its lication to an individual must be re or less pin-pointed in time. pian's definitions are rather neat, as far as I can see, they do not nge in the slightest the line of ument of my editorial.

Very truly yours,
M. C. Pease

Microwave Component News from SYLVANIA

NEW Microwave Diodes withstand 150°C



Average Storage Life At 150°C (1N23C)

Sylvania develops new fabrication techniques that bring standard microwave diode heat capabilities up to 150°C at no increase in cost

Now, microwave design engineers can get the high temperature advantages of specialized premium diodes without any of the cost or delivery disadvantages, by specifying Sylvania microwave diodes. Through improved processing techniques and high-temperature bonding agents, Sylvania has succeeded in raising the temperature capabilities of its S and X-Band microwave diode lines by 60°C!

For the design engineer, these new diodes can result in substantial reductions in air cooling equipment requirements and associated cabling. They also open new design possibilities in commercial applications where ruggedness and price can be controlling factors.

Contact your Sylvania representative now for full particulars on these new Sylvania microwave diodes or write the factory directly at the address below.

Sylvania high temperature microwave diodes

Micro-Min Diodes	Forward-Reverse & Matched Pairs	Double Ended Diodes
1N830 (D4050)	1N21B 1N23B	1N416B 1N415B
1N831 (D4064)	1N21C 1N23C	1N416C 1N415C
1N832 (D4065)	1N21D 1N23D	1N416D 1N415D
1N833 (D4063)	1N21E 1N23E	1N416E 1N415E

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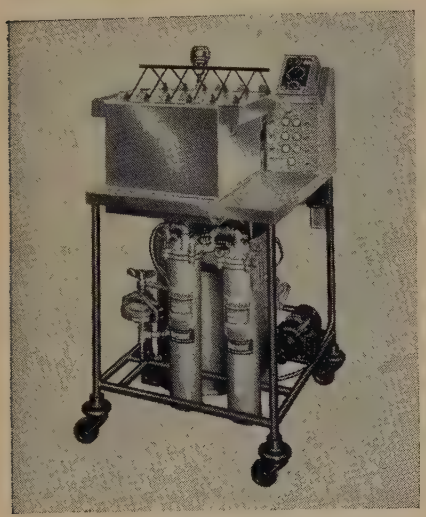
BARNSTEAD NEW TRANSISTOR WASHER

FOR WASHING and RINSING TRANSISTORS, DIODES, RECTIFIERS, TUBE PARTS and MATERIALS SUCH AS SILICON AND GERMANIUM



Maintains 15,000,000 OHM ultra-pure water while conserving make-up water through special re-purification cycle.

Best results with faster rinsing and fewer rejects are obtained when ultra-pure, hot water is employed in washing and rinsing of transistors, diodes, and other electronic components. The Barnstead Transistor Washer conserves thousands of gallons of water each day as it repurifies the pure, hot water keeping it free of organic impurities, and submicroscopic particles to 0.45 microns. Completely factory-assembled, ready for operation.

Partial Listing of Firms Using BARNSTEAD TRANSISTOR WASHERS

Clevite Transistor, Waltham, Mass.; Motorola, Inc., Phoenix, Arizona; Western Electric Co., Lauderdale, Pa.; Delco, Dayton, Ohio; Minneapolis-Honeywell, Brighton, Mass.; Bell Telephone Laboratories, Somerville, N. J.; Texas Instrument Co., Dallas, Texas and many others.

WRITE FOR CATALOG —

WATER STILLS, steam, gas and electric with capacities from ½ to 1000 g.p.h. **REGENERATIVE TYPE DEMINERALIZERS,** 50 to 2,500 or more g.p.h. **SUBMICRON FILTERS,** 400 or more g.p.h. Submicroscopic filtration to 0.45 microns

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STILL & STERILIZER CO. Inc.

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CHICAGO MUlberry 5-8180	PHILADELPHIA LOcust 8-1796	LOS ANGELES RYan 1-6663
JOHNSON CITY 3113	SAN FRANCISCO TEmplebar 2-5391	CHATTANOOGA 6-5863

48 Lanesville Terrace, Boston 31, Mass.

FIRST IN PURE WATER SINCE 1878

INDUSTRY NEWS

F. E. VACCARO NAMED MANAGER

Appointment of Frank E. Vaccaro as Manager, Microwave Advanced Development, RCA Electron Tube Division, was announced today by Hans K. Jenny, Manager, Microwave Engineering.

A native of Memphis, Tennessee, Mr. Vaccaro is a graduate of the University of Tennessee and the Stevens Institute of Technology. He joined RCA in 1949 as a Specialized Engineer Trainee, later being assigned as an engineer in the Microwave Tube Development activity. In 1956 he was promoted to Engineering Leader and was transferred to the newly established Microwave Advanced Development group of the Electron Tube Division located at the David Sarnoff Research Center, Princeton, N.J.

Mr. Vaccaro is the author of several technical papers on microwave tubes and holds many patents on microwave devices. His memberships include Tau Beta Pi, Eta Kappa Nu and the Institute of Radio Engineers.

Mr. Vaccaro resides at 10 Hamlin Road, Lawrence Brook Village, New Brunswick, N.J.

• • •

HERMAN CHAIT APPOINTED

Herman N. Chait has been appointed chief scientist of Monogram Precision Industries, Inc. — Cascade Research Division, Martin Stone, executive vice-president, announced.

Chait was an electronic scientist and solid state physicist with the Naval Research Laboratory in Washington, D.C. prior to joining Monogram. Earlier this year, he was presented with an Award of Merit

(*Continued on page 14*)

YTTRIUM-IRON GARNET

Actual Size

SINGLE CRYSTALS

for MICROWAVE APPLICATION

FERRIMAGNETIC SINGLE CRYSTAL YIG IS NOW AVAILABLE FOR MICROWAVE DEVELOPMENT.

LOW-LOSS YIG NOW ALLOWS GREATER FLEXIBILITY IN THE DESIGN OF

Pass or rejection band tunable filters

Compact circulators, isolators and gyrators

Ferrite parametric amplifiers

VHF and UHF components

Magneto-optical devices

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MICROWAVE CHEMICALS LABORATORY, IN

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CIRCLE READER SERVICE CARD

EXPERIENCE AVAILABLE FROM

LEADERS IN THE FIELD OF MICROWAVE FREQUENCY MEASUREMENT AND CONTROL

Leadership is no accident. And here at Frequency Standards the leadership we enjoy in our field is the product of many things. It is the result of 15 years of excellence in precision manufacturing.

Assuredly, it is also the result of eight years of intense design and development work in the field of microwave frequency measurement and control. You will find evidence of our leadership in the important developments we have made for the Government's overall defense program. And in the fact that ours is the first Company able to produce standard lines of Microwave Frequency measuring and controlling devices, as well as specific design work for industry.

Send for details on what has been described as the most advanced engineering staff in this field—and literature on our standard lines and design facilities. Address: Frequency Standards, Box 504A, Asbury Park, N. J. PRospect 4-0500. Or your nearest representative in all principal cities.

FREQUENCY STANDARDS

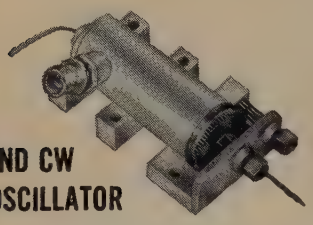
HARVARD

A DIVISION OF INVESTORS, INC.

NEW!

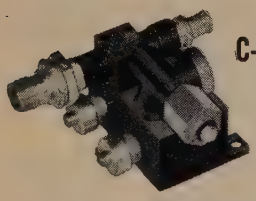
C-Band *System-Tested* MICROWAVE COMPONENTS

Engineered to meet complete Military Missile Specifications



C-BAND CW OSCILLATOR

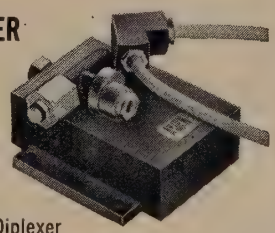
- Minimum 3 mw Power Output
- Adjustable Tuning over a range of 500 mc
- Tube—Triode GZ 5139
- Miniaturized—only 4" long, 1¾" wide, 1¼" high (excluding connector)



C-BAND BEACON FRONT END ASSEMBLY

- An exceptionally compact, lightweight unit, featuring low loss and ultra-high selectivity.
- Extremely small—only 2½" x 2½" x 2"

C-BAND FILTER MIXER DIPLEXER



- Mixer and Diplexer (non-tunable) operate as an integral part of the Filter
- Unit features minimum Insertion Loss, Rejection Bandwidth and Input VSWR
- Tuning Range—minimum 500 mc

WRITE for prices and delivery.

AVION

FOREMOST IN AVIONICS

ACF INDUSTRIES INCORPORATED

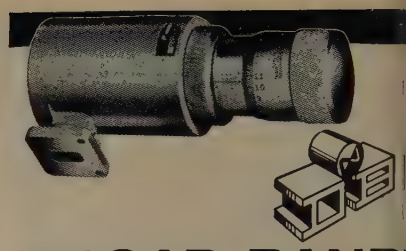
AVION ACF AVION DIVISION

11 Park Place, Paramus, N. J.

INDUSTRY NEWS

from the Department of the Navy for his important contributions in the microwave art.

Under Chait's supervision, Cascade Research expects to enter the complete microwave antenna systems field, and to broaden its line to include all microwave components and ferrite devices. The antenna systems to be developed and built by Cascade will vary from ultra high frequencies (UHF) to the high microwave frequencies.



BROAD BAND CAVITY WAVEMETERS

—gas filled for sustained accuracy

Accuracy is so high these instruments may be used as secondary standards. Units are unaffected by changes in humidity, altitude or barometric pressure. Only 12 sizes serve from 2.6 KMC to 140 KMC. You save budget money on the number of sizes needed. Literature on request.

DE MORNAY BONARDI

DE MORNAY–BONARD

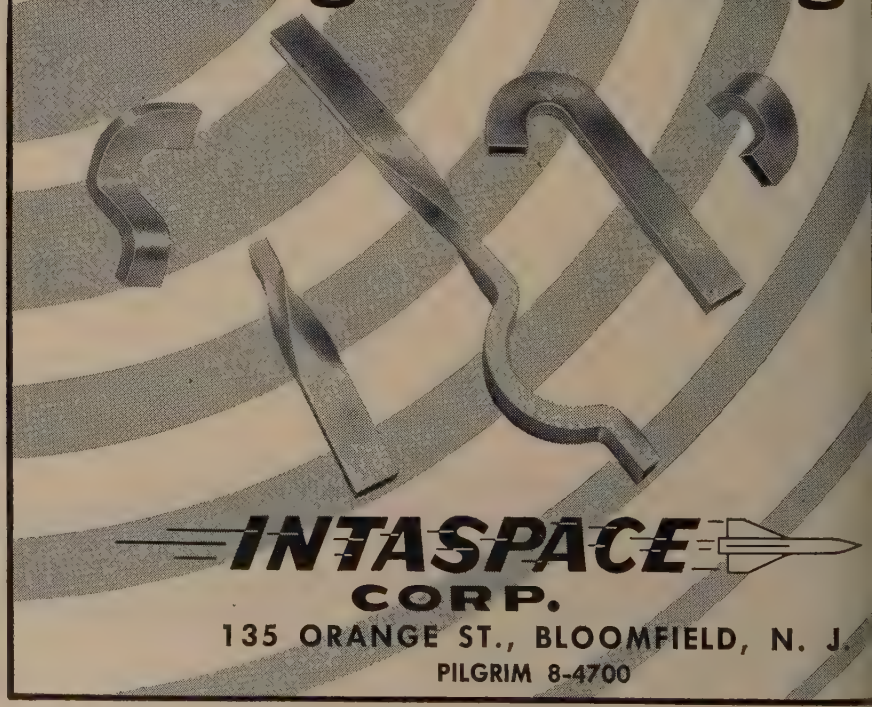
780 SOUTH ARROYO PARKWAY • PASADENA, CALI

CIRCLE READER SERVICE CARD

Waveguide

specialists in close tolerance

Bending and Forming



INTASPACE CORP.

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PILGRIM 8-4700

CIRCLE READER SERVICE CARD 13

SINGLE-GUN COLOR TUBE RETROFITS!

We've been hearing comments that have the ring of praise about them. They have been comments on the simplicity of our Lawrence-type color display tube, 5CGP29. We build other color and monochrome cathode ray tubes, *e.g.*, for applications requiring high definition of a hush-hush nature, or for fine character writing and many other applications. But let us discourse on the 5CGP29.

First of all it adapts to a great many equipments now limited by monochrome. It adapts with the same yoke you are now using and without the need to build a six-foot voltage-control console. The 5CGP29 does not have fussy requirements.

Post-Deflection Focusing is incorporated in the design. The electron beam paths are directed through an array of grid wires to an aluminum-backed phosphor screen on the face of the tube. Switching voltages on adjacent grid wires change the impact point of the focused beam. None of this is particularly critical in operation. And the operating voltages are such as not to produce what the low-temperature lab men call "thermal chaos."

There is very likely nothing more dramatic in the world of electronics than the face of a 5CGP29 discriminating between different classes of information in extra dimensions with bold colors. Military people appreciate it when, again with different colors, the 5CGP29 promptly discriminates in radar between hazardous and non-hazardous objects, or between friendly and unfriendly targets, for example.

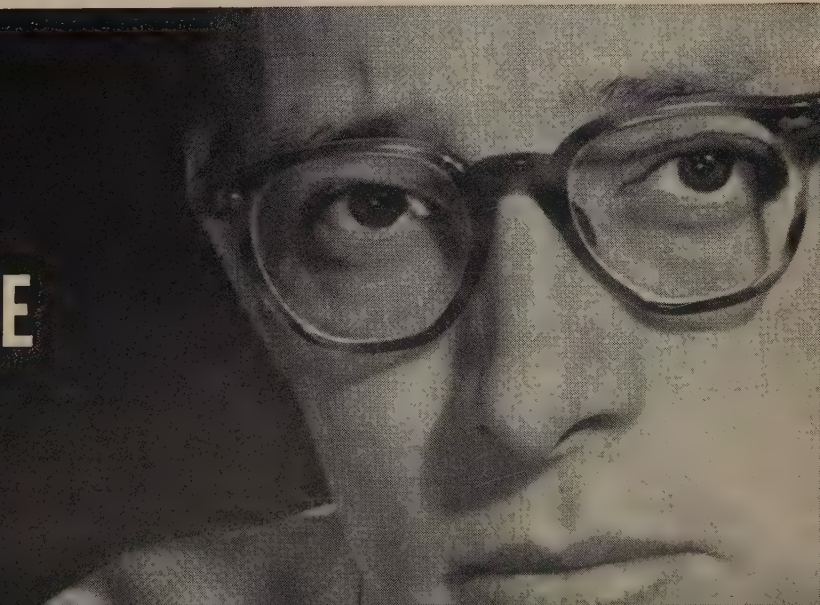
A number of commercially available phosphors, with differing responsive qualities, afford wide variations in persistence and colors. There are dozens of uses for the tube in science, industry, and the military service. Let us tell you about them. Electronic Display Laboratory, Litton Industries Electron Tube Division, Office M4, 960 Industrial Road, San Carlos, Calif.

CIRCLE READER SERVICE CARD 19

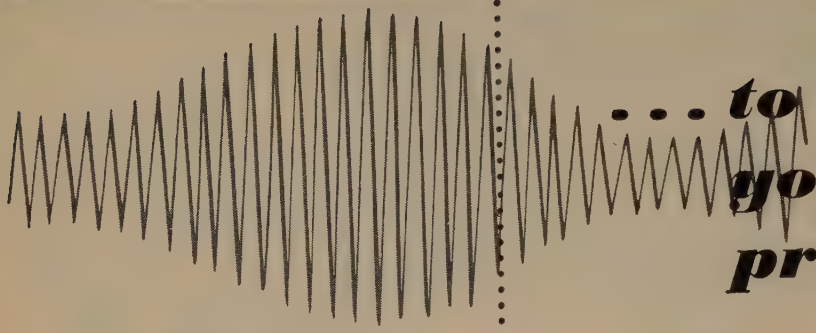
LITTON INDUSTRIES **Electron Tube Division**

MAGNETRONS • GAS DISCHARGE TUBES • CARCINOTRONS • TRAVELING WAVE TUBES
KLYSTRONS • BACKWARD WAVE OSCILLATORS • NOISE SOURCES • DISPLAY TUBES

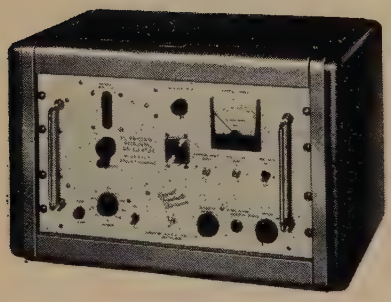
CAPABILITY THAT CAN CHANGE YOUR PLANNING



MICROWAVE INSTRUMENTS



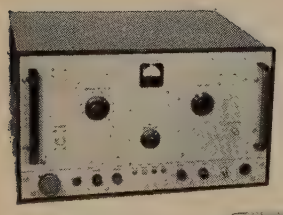
. . . to improve your products

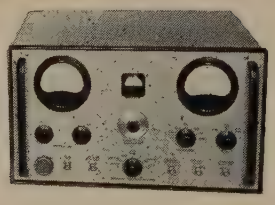


. . . generation

. . . *ultra-stable oscillator 814*

Ultra-stable, high-power, tunable . . . short-term stability is 5 parts in 10^8, long-term, 5 parts in 10^6. Twenty-one models are available to cover complete spectrum from 2500 to 25,000 mc/s. Special units to 60,000 mc/s. Power output ranges from 20 milliwatts to 1.5 watts. Tunable, directly calibrated dials read frequency to 0.1 percent.





. . . measurement

. . . *stability tester 5009*

Exceptional, highly-advanced instrument for precision measurement of change, rate of change and stability from change. Four models measure drift and fm in frequency bands from 1120 to 14,500 mc/s. Meters calibrated to read peak fm deviation in cps and drift in kc. Accurate . . . at S-band measures deviation to less than 1 cps — at X-band to 10 cps. Instantaneous readings and continuous monitoring.

LABORATORY FOR ELECTRONICS, INC.

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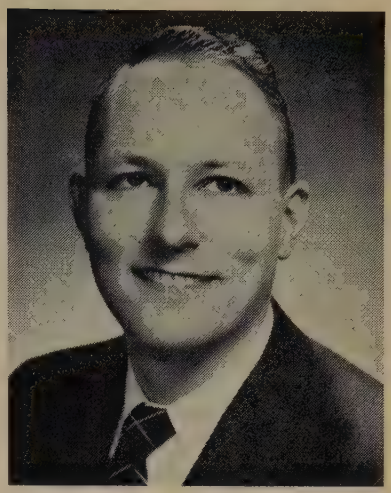
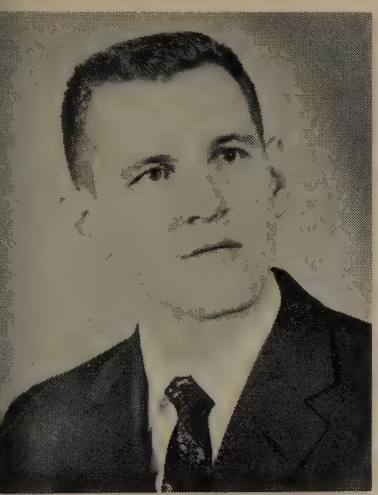


OBERT C. HANSEN was born August 1926 in St. Louis, Missouri. hooling at the Missouri School of Mines and Metallurgy was interrupted 1944 for a period in Navy R. T. School. The B.S. in E.E. was obtained om the School of Mines in January, 1949. M.S. and Ph.D. degrees were anted by the University of Illinois in 1950 and 1955. While at the Uni- rsity of Illinois he worked in the Antenna Laboratory. Since that time has been in the Microwave Laboratory of Hughes Aircraft Company here he is presently Senior Staff Engineer.

He is a member of Tau Beta Pi, Sigma Xi, Eta Kappa Nu, Phi Kappa hi, the American Physical Society, and Commission VI of URSI.

In 1957 Dr. Hansen was Professional Groups Coordinator for the os Angeles Section of IRE, and was Co-Chairman of the 1957 RTCA- RE Symposium. He was Chairman of the Technical Program Committee r the 1958 WESCON-IRE Convention. Currently he is Chairman of e PGAP Sub-committee on Standards for Testing Antennas, and is Vestern Vice-Chairman of the IRE Professional Groups Committee. He is so a member of the Administrative Committee of PGMTT.

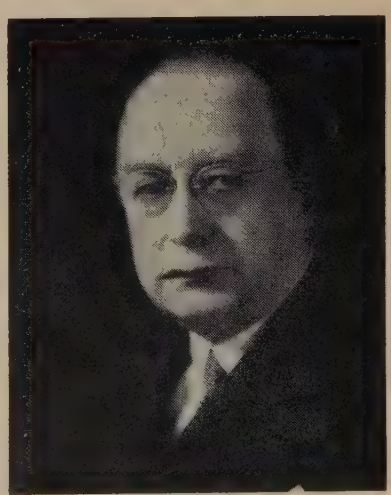


RICHARD J. MOHR was born in New York City, N.Y. on April 12, 1930. He received his BEE degree from the City College of New York in 1952 and his masters degree in electrical engineering from the Polytechnic Institute of Brooklyn in 1957.

In January of 1958, Mr. Mohr joined the engineering staff of FXR, Inc. where he is presently engaged in the design of microwave components for systems and for the FXR line of precision microwave test equipment.

Before coming to FXR, Inc., he was employed at Airborne Instruments Laboratory where he designed low noise microwave front ends and sensitive UHF and VHF receivers for scatter propagation and radio astronomy studies.

Mr. Mohr has two patents pending in the field of microwave components.



EORGE CLARK SOUTHWORTH was born at Little Cooley, Pa., on ugust 24, 1890. Dr. Southworth did undergraduate work at Grove City ollege and graduate work at Columbia and Yale. During World War I e was occupied with research work at the Bureau of Standards and Yale niversity. He was with the Bell System from 1923 until 1955, when he etired to become a consultant. He is the author of a score or more of cientific papers on diversified radio subjects. His work culminated in 1950 a 675-page textbook on microwave techniques, "Principles and Applica- ons of Waveguide Transmission."

For his work in waveguides, Dr. Southworth received the 1938 Morris iebmann Prize of the IRE, and in 1947 the Stuart Ballantine Medal of e Franklin Institute. He is a fellow of the IRE, the American Physical ociety, and the American Association for the Advancement of Science.

Dr. Southworth has been a valued friend and advisor to *the microwave urnal* since its inception.

Under development at I-T-E:

GIANT EYES FOR NEW DEW LINE RADARS

I-T-E has again been entrusted with the design and manufacture of a complete radar antenna system for use in America's air defense network. A major supplier of antenna systems for the original DEW line—extending from the Aleutian Islands, through Alaska and across Canada, to Eastern Baffin Island—I-T-E is now developing a giant new antenna system for use in the extension of the DEW line across Greenland. I-T-E's customer is Bendix Radio, Division of Bendix Aviation Corporation.

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OW NOISE ANTENNAS

obert C. Hansen, -- Microwave Laboratory -- Hughes Aircraft Co.

Introduction

Performance of many electronic systems is limited by ise, both internally generated noise and external noise ich finds its way into the system. Communications, ar, radio astronomy, and similar systems are vulnerable external noise since the receiving antenna allows some se to enter the system along with the desired signal. is paper surveys the basic factors of noise in antenna tems, explains the antenna merit factor, and discusses design of low noise antennas.

A study of noise in antennas can logically be divided o two frequency regions. In the range up to about 30 mc and hf bands), antennas are typically omnidirectional one plane and have a dipole "figure eight" pattern in other plane. At the same time atmospheric (or ter- trial) noise predominates in this frequency range. It is atively easy to construct a receiving antenna sufficiently ge that the input noise is greater than the receiver noise, will be shown in Section IV. Increasing the antenna e beyond this point does not enhance the signal to noise io.

At higher frequencies both antenna and noise charac- stics are different. Antennas are typically highly direc- e with large gains. Noise sources now include land, sea, nosphere, radio stars, and galaxies, as well as the com- n impulsive noises. Receivers, especially at microwave quencies, are frequently noisy. A noise figure of merit, ful for both antennas and receivers and to be defined r, is "effective noise temperature." A typical crystal ter receiver has a noise temperature of 2010°K (9 db) ile a typical low noise TWT receiver has a noise tem- ature of 627°K (5 db).

Typical antenna temperatures, as will be seen later, range und 200°K; thus system performance has in the past n severely limited by the receiver noise. Recent maser parametric amplifier developments have produced r-f plifier temperatures as low as 8°K. With these new ices the microwave systems are in a class with the er frequency systems in that the major noise source now the antenna. However, because of the great flexi- ty in designing microwave antennas it is possible to gn for a reduced antenna noise temperature.

ll the foregoing remarks apply to receiving antennas. nough system signal to noise ratio is certainly affected he design of the transmitting antenna, noise does not ctly affect that design. The principal transmitter design meter is efficiency, both aperture excitation efficiency reduction of heat and mismatch losses, neither of which affected by noise. Consequently this antenna noise y will apply principally to receiving antennas. Where same antenna is used for both transmitting and re- ing, a compromise between transmitting efficiency receiving noise quality factors must be made. The section will discuss these quality factors.

Noise Factor and Temperature

Most noise in the radio spectrum is either random mal noise or impulsive noise. The latter will not be considered as it is usually local (man-made) and in the lower frequency ranges. Thermal noise results from the random motion of particles in matter and covers all frequencies; for a resistor, this random motion produces a noise voltage[1]

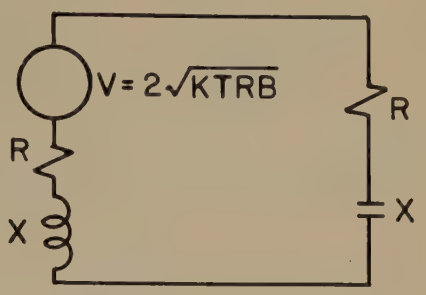


Figure 1 — Noise Power Circuit.

$$V = 2\sqrt{KTRB} \qquad (1)$$

where V is an rms value, K is Boltzman's constant 1.37 $\times$ 10^{-23} joule/°K, T is absolute temperature (°K), R is resistance in ohms, and B the bandwidth in cycles per second. If we want to extract this noise power, assuming the resistor to be associated with a reactance, we place a conjugate matched impedance as a load, see Figure 1.

The maximum noise power (due to V) in the load is just KTB, which concurs with the well-known fact that the noise power available from a resistor or other thermal noise source is independent of the resistance, depending on the bandwidth and ambient temperature alone. The load is also a noise source; the random nature of the noise allows the noise powers to be added directly.

System performance is usually studied by the use of network building blocks; in this instance we are interested in the noise quality factors of a two terminal pair network. These quality factors are three in number: the noise factor F_N, degradation factor F_D, and sensitivity factor F_S. Notation differs widely; that most often found in the literature is used here. The noise factor (sometimes called noise figure) is the ratio of noise power out of the network to noise power out of a noise free network, both per unit bandwidth and at the standard temperature[2] $T_o = 290°K$. If network power gain is G, the noise power for a noise free network is just KT_oBG, where the input (which is a noise source!) is at temperature T_o. Thus,

$$F_N = \frac{KT_oBG + P_N}{KT_oBG} \qquad (2)$$

where P_N is the noise produced in the network itself. Because available noise power is directly related to absolute temperature, it is logical to write an *effective noise temperature* T (sometimes called excess noise temperature), which would exactly produce P_N. So

$$P_N = KTBG, \quad F_N = 1 + \frac{T}{T_o} \qquad (3)$$

Note that T is referred to the input terminals, and that the ambient temperature of the network is $T_o = 290°K$. Table 1 gives an idea of the correspondence.

Table 1.

Effective Noise Temperatures and Noise Factors

F_N		T
db	*ratio*	*degrees Kelvin*
0	1.00	0
1	1.26	76
2	1.59	171
3	2.00	290
5	3.16	627
8	6.31	1540
10	10.0	2610

There is an equivalent way of defining the noise factor: F_N is the ratio of the S/N ratio of a noiseless network to the S/N ratio for the actual network, again per unit bandwidth and at T_o.

The degradation factor is defined in an exactly analogous manner except that the source is at ambient temperature T_A. Because the operating S/N ratio is degraded by the factor $1/F_D$ due to the noise in the network, F_D is called degradation factor. We have

$$F_D = \frac{K T_A B G + K T B G}{K T_A B G} = 1 + \frac{T}{T_A} \tag{4}$$

The noise and degradation factors are related by

$$(F_D - 1)\ T_A = (F_N - 1)\ T_o \tag{5}$$

The third factor, the sensitivity factor F_S, gives the degradation of the absolute sensitivity, as will be shown shortly. This factor is the ratio of output noise power with actual source at T_A to that for the ideal network at T_o.

$$F_S = \frac{K T_A B G + K T B G}{K T_o B G} = \frac{T_A + T}{T_o} \tag{6}$$

It is easy to show that F_S is related to the noise and degradation factors by

$$F_S\ T_o = F_D\ T_A,\ F_N - 1 = F_S - \frac{T_A}{T_o} \tag{7}$$

All three factors as defined are for a spot frequency. For evaluating performance over a bandwidth, average (or integrated) factors are defined for F_N, F_D, and F_S:

$$F = \frac{\int K T_o F G\, dB}{\int K T_o G\, dB} \tag{8}$$

Now to consider sensitivity. The definition [3] of sensitivity is, "the minimum input signal that will produce the desired output signal, "thus the more 'sensitive' (in the common usage) is a receiver, the smaller its 'absolute sensitivity.' Suppose we now evaluate a two terminal pair network in terms of sensitivity. Let the desired output be a stipulated S/N ratio, and the network gain be G, see Figure 2. The input is characterized by signal S_A, temperature T_A. Then

$$\frac{S}{N} = \frac{S_A G}{K T_A B G + K T B G} = \frac{S_A}{K B (T_A + T)} = \frac{S_A}{K T_o B F_S} \tag{9}$$

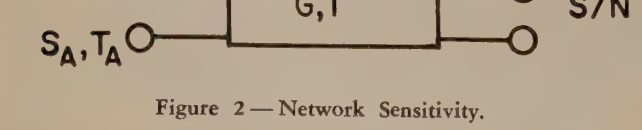


Figure 2 — Network Sensitivity.

For a given S/N ratio we want to minimize S_A, wh also minimizes F_S (or vice versa). Given the sensitiv factor F_S, the input signal must be sufficiently large produce the necessary S/N ratio. Recalling that F_S $\frac{T_A + T}{T_o}$ if the receiver temperature T is small compa with T_A, then the sensitivity is nearly

$$S_A \simeq KB \frac{S}{N} T_A \tag{1}$$

and the system sensitivity is directly related to the ante effective noise temperature. *The design objective sho be to minimize T_A and at the same time make S_A la enough to realize the specified S/N.* Similar results h been obtained by Hausman and others for communicat systems.[4, 5] Because receivers consist of many stages, i necessary to derive noise factors and temperatures for caded networks.

III. Cascaded Networks

Consider two networks in cascade, as shown in Figur

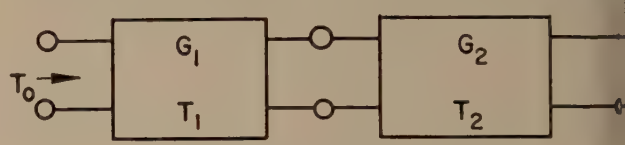


Figure 3 — Networks in Cascade.

The noise power at the output is

$$K T_o B G_1 G_2 + K T_1 B G_1 G_2 + K T_2 B G_2 \tag{1}$$

giving a noise factor

$$F_N = \frac{T_o G_1 G_2 + T_1 G_1 G_2 + T_2 G_2}{T_o G_1 G_2} \tag{1}$$

When this is generalized to many stages the result is

$$F_N = F_{N1} + \frac{F_{N2} - 1}{G_1} + \frac{F_{N3} - 1}{G_1 G_2} + \frac{F_{N4} - 1}{G_1 G_2 G_3} + \cdots \tag{1}$$

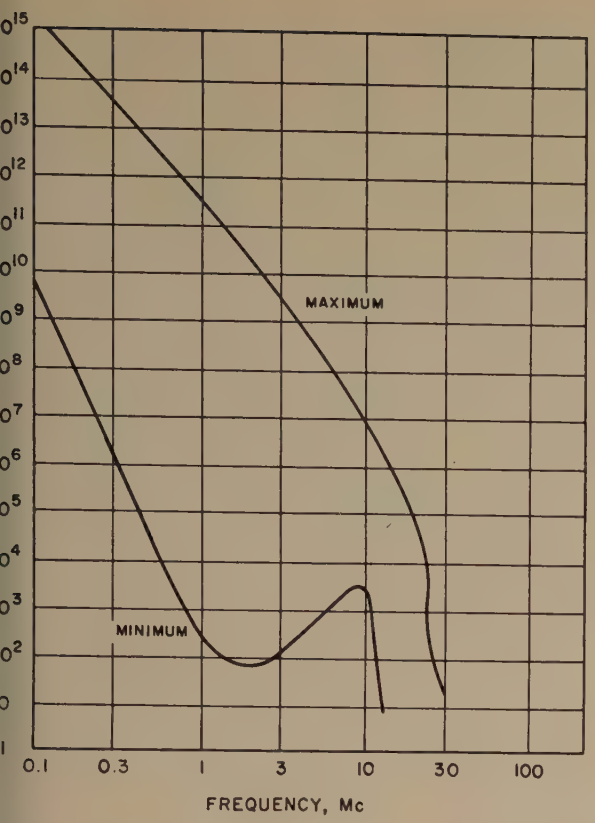
Similarly the overall effective noise temperature is sim

$$T = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \frac{T_4}{G_1 G_2 G_3} + \cdots \tag{1}$$

Even though a receiver has many stages, the sensitivity sults (9) and (10) can be approximated very well using T_1, the first stage temperature. These formulas not however, take into account mixer noise introdu through the image channel, or parametric amplifier n coupled to the idler channel.

IV. Antenna Temperature at Low Frequencies

Now that the quality factors have been established, next task is to devise a method for computing an ante effective noise temperature. As mentioned earlier, beca size limitations preclude in most cases any tailoring of antenna pattern, incident noise is usually determined fr simple measurements. Noise due to loss and impeda mismatch in the antenna must also be accounted This is accomplished by the usual expedient of letting antenna equivalent circuit consist of a loss resistance series with the radiation resistance plus reactances. Stri speaking, the lossy antenna as a transducer should treated as a four terminal network, with the radia



re 4 — Atmospheric Noise Limits for Vertical Dipole, after Hayden.

e as input; copper, dielectric, and impedance mis-ch losses would constitute the loss of the antenna ver. But since these losses are usually only a few per-, the noise produced by these losses can be lumped the radiation noise with very small error. The tive temperature of resistors in series can be com-d from the sum of rms voltages. With n resistors otal resistance R,

$$V^2 = \sum_n V^2_n, \text{ or } PR = \sum_n P_n R_n \tag{15}$$

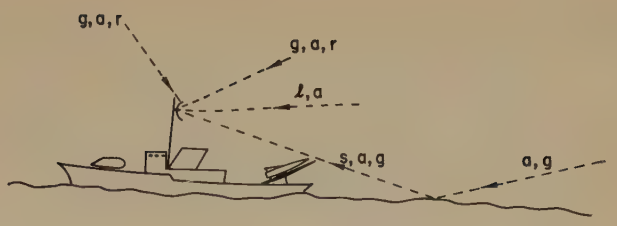
$$T = \sum_n T_n \frac{R_n}{R} \tag{16}$$

he temperature due to the heat loss contributes to the noise temperature in proportion to the ratio of loss ance to total resistance and similarly the incident or tion noise temperature contributes in proportion e ratio of radiation resistance to total resistance.

he incident noise temperature is determined by meas-ent of the received power with a low loss antenna. ough the atmospheric noise levels vary greatly with h and latitude, the values of Figure 4 are representa- and indicate the very high noise levels at hf.

Antenna Temperatures at Microwave Frequencies

the uhf region and above, the noise levels are con-ably lower than at hf, and the spatial distribution is onger close to isotropic. Now the antenna pattern be taken into account. In addition the multitude of es poses a problem. For example, the antenna may ne noise source in the partially reflecting surface of ond noise source (e.g., land or sea). Both sources ibute noise; how do we calculate the effective tem-



s – SEA NOISE
a – ATMOSPHERIC ABSORPTION NOISE
g – GALACTIC NOISE
r – RADIO STAR NOISE
ℓ – LAND NOISE

Figure 5 — Typical Input Noise Rays.

perature? We use reciprocity and the ray temperature concept. Reciprocity allows us to say[7] that the noise received by the antenna from each direction (through a small solid angle) is proportional to the power absorbed in that direction when the antenna is transmitting, times the ambient temperature of the absorbing body. In practice, the three-dimensional antenna pattern is divided into a number of rays or slices. For an example, a narrow beam ship radar antenna may be pointed roughly at the horizon, see Figure 5. Part of the ray hitting the sea is absorbed, representing noise at the sea temperature; the rest of the energy in that ray travels through the atmosphere during which additional energy is absorbed. The remainder is lost in galactic space. Thus for that ray, at least three noise sources; sea, air, and space, each with a different temperature, contribute input noise. The ray temperature is found by adding these contributions, weighted according to absorption.[8] If the antenna is covered by a radome, the power loss (and noise) should be treated as a four terminal network in cascade, with its own noise figure. This is especially true for hot radomes where the dielectric material loss and high ambient temperature both produce appreciable noise.

Let each ray or slice occupy the solid angle Ω (all space is 4π steradians). Then the i^{th} ray will have a fraction of the total radiated power given by $g_i \Omega/4\pi$, where g_i is the gain of the i^{th} ray. This ray may be incident in turn upon several objects. From (15) and (16), the equation for power can be written in temperatures. Because the absorption of energy by a body is a function of the incidence angle, let α_{ki} be the fraction of ray i that travels to and is absorbed in the object or area K. Then the total effective noise temperature T is

$$T = \sum_k T_K \sum_i \alpha_{ki}\, g_i \frac{\Omega}{4\pi} \tag{17}$$

where $\sum_k \alpha_{ki} = 1$ and T_K is the temperature of the k^{th} object.

Discrete sources (radio stars) may be dealt with separately if the angle subtended by each is small. Reversing the sums allows the "ray or slice temperature" to be used, where T_{ray} is the temperature for a delta function pattern.

$$T = \sum_i \frac{\Omega}{4\pi}\, g_i \sum_k T_K\, \alpha_{ki} \tag{18}$$

where

$$T_{ray} = \sum_k T_k \alpha_{ki} \text{ for } i^{th} \text{ ray or slice} \tag{19}$$

To compute the antenna noise temperature (exclusive of impedance mismatch loss), we must find

a) heat loss in feed, reflector, etc.
b) discrete source intensity
c) temperature and gain of each ray or slice.

VI. Examples

For dish type antennas, the circular aperture serves as a good model. In order to determine the approximate apportionment of the power among the main beam, sidelobes, spillover, etc., calculations have been made for circular apertures with uniform and $(1 - \rho^2)$ taper, of the percentage of total power contained within the main beam and within the half power points. Total power (the volume of the rotational pattern) is found from gain formulas to be $\lambda^2/\pi a^2$ for a uniform case, and $4\lambda^2/3\pi a^2$ for the tapered aperture. Power in the beam for the uniform case is given by

$$2\pi \int_0^{\theta_0} \left[\frac{2 J_1 (u)}{u} \right]^2 \sin \theta \, d\theta \tag{20}$$

where $u = ka \sin \theta$, and θ_0 is the first null. For $u^2_0/k^2 a^2 \ll 1$, which is valid for diameters as small as five wavelengths, (20) can be replaced by

$$\frac{2\pi}{k^2 a^2} \int_0^{u_0} \frac{4 J^2_1 (u) \, du}{u} \tag{21}$$

in which u_0 is the first zero of the pattern. The important feature is that the fraction of power in the main beam, given by dividing (21) by the total pattern volume, is *independent of the antenna diameter.* The figures obtained by numerical integration are in Table 2.

TABLE 2.
Circular Aperture Power Division

Taper	*Percent Power in Main Beam*	*Percent Power Between Half Power Points*	*Percent in Sidelobes*	*Sidelobe Level (db)*
Uniform	83	47	17	17.6
$(1 - \rho^2)$	98	61	02	24.6

However, these ideal figures do not allow for feed spillover, cross polarization, aperture blockage, and back lobes. In practice, the gain factor limit seems to be about 65 percent (gain factor is the ratio of measured gain to theoretical gain from a uniformly illuminated circular aperture). Because 25 db sidelobes are about the best actually realized with dish antennas (without special "tunnel techniques"), this will be taken as typical, although many dishes in use have considerably poorer sidelobe ratios. The 0.65 gain factor can be thought of as the product of two factors, one due to the taper (0.75), the other due to spillover, back lobes, etc. With the use of the .65 gain factor the values in Table 2 were recalculated for the 25 db sidelobe case giving 85 percent of power in the main beam, and 15 percent in side and back lobes. These figures are fairly realistic.

To give a realistic idea of the contribution from the several sources, take as an example, the antenna of Figure 5, pointed at the horizon. Assume 3000 mc and a heat l of 3 percent. For an accurate computation, the rotatio pattern would be divided up into wedge shaped slices, gain and angle of incidence to the sea would be found each slice, etc., with the slice effective temperatures be found and added as explained in the preceding secti However, for a quick sketch of the magnitude of

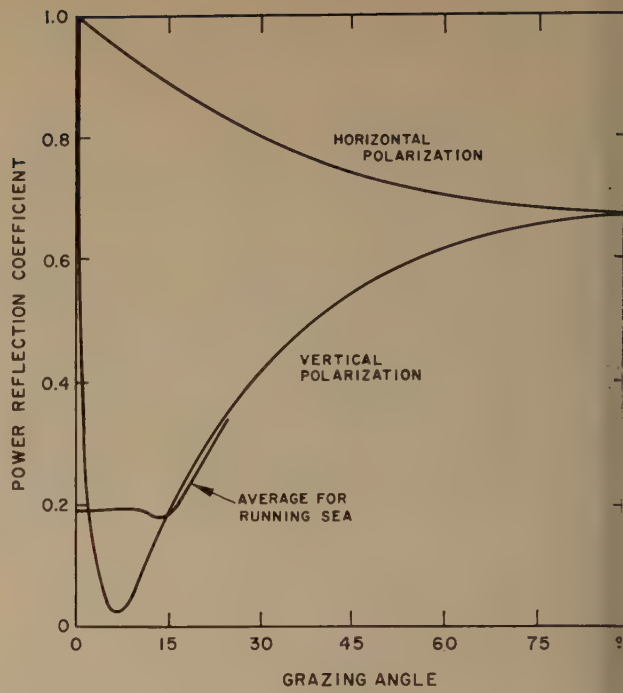


Figure 6—Smooth Sea Water Reflection at 3000 Mc, T = 10

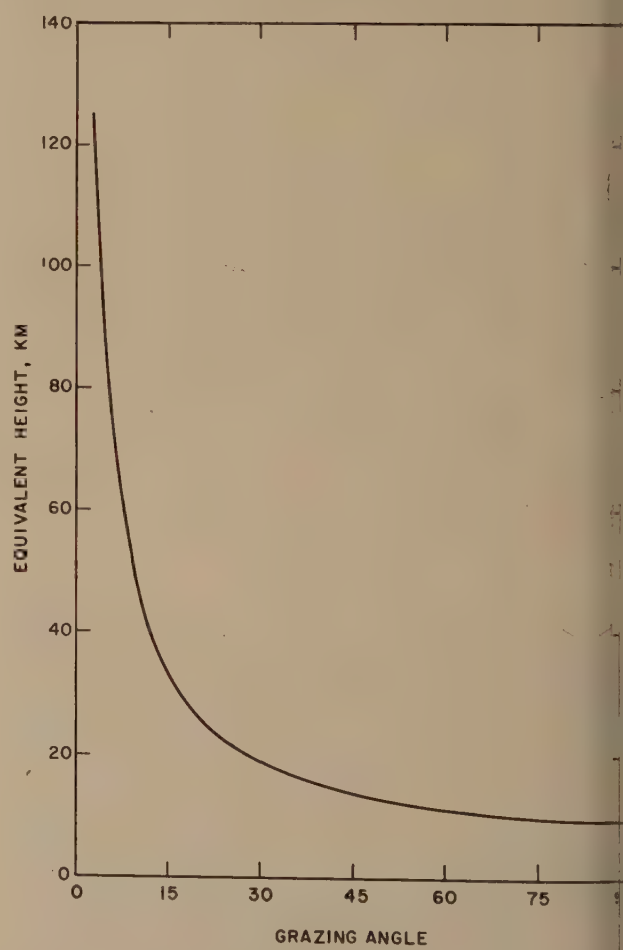


Figure 7 — Equivalent Uniform Atmosphere.

veral components, the main beam will be divided into ly two slices; side and back lobes will be likewise divided to upper and lower. Land is almost a complete absorber. a absorption is found from the Fresnel reflection factors Figure 6 and from an average of grazing angles based Katzin's representation of a running sea by a collection small plane facets of random size and slope.[9] For the wer half of the main beam, assuming a beamwidth of veral degrees or less, the running sea reflection coefficient (at 3000 mc) is around 0.19. For the 19 percent ower scattered by the sea, atmospheric absorption is a urce of noise, not to be confused with "atmospheric oise" prevalent below L-band. Because both the dielectric nstant and ambient temperature of the atmosphere ange with altitude, calculation of the absorption is very fficult. Calculations of noise temperature due to atmospheric absorption range as high as 100°K at grazing cidence.[10] A simplified procedure seems adequate however. The wave attenuation is determined[11] at 3000 mc; ly oxygen absorption is important, and $\alpha = 0.0065$ b/km. Then the atmosphere is replaced by a "uniform eight" atmosphere; the equivalent height is shown in gure 7. The angles of incidence are averaged, and the sorption found. For the main beam, the average equivant height is 110 km, giving an attenuation of $0.0065 \times 110 = 0.72$ db, or an absorption of 0.15. For sidelobes, the average height is 15 km giving 0.021 absorption. The remainder of the power is incident upon galactic space. Available plots of galactic noise seem to go up to L-band only.[12] Only crude guesses can be made of average galactic noise temperature at S-band; our guess is 10°K. For the actual illustrative calculation, assume the 3 percent heat loss is included in the main beam 85 percent.

Thus the sea (and land) noise is a major contribution whenever the main beam intersects sea or land. Heat loss on the other hand for dish antennas is a very small factor.

A similar case has been computed by Airborne Instruments Lab. for an L-band tropospheric scatter antenna for 0/H propagation,[11] see Figure 8.

At X-band where galactic noise is perhaps a degree or less, the clear sky example would produce, for side and mainlobes and for feed and dish copper loss, about 29°K. This figure is very close to that quoted by Giordmaine * et. al. for the N.R.L. fifty (50) foot dish antenna for spillover, atmospheric absorption, and feed loss at X-band.

Fixed stars such as the quiet sun, Cassiopeia A, Cygnus A usually give less than a degree unless the main beam is pointed at them.

* In a paper to be published.

		LOWER HALF MAIN BEAM, GAIN = 0.41			
a Absorption	.81	Ambient Temperature	300°K	.41 x .81 x 300 =	100°K
tmospheric Absorption	.15	Ambient Temperature	290	.41 x .19 x .15 x 290 =	3
alactic Absorption	1.00	Ambient Temperature	10	.41 x .19 x .85 x 10 =	1
					104°K
		UPPER HALF MAIN BEAM, GAIN = 0.41			
mospheric Absorption	.15	Ambient Temperature	290°K	.41 x .15 x 290 =	18
alactic Absorption	1.00	Ambient Temperature	10	.41 x .85 x 10 =	3
					21°K
		LOWER SIDE AND BACK LOBES, GAIN = 0.075			
erage Sea Absorption	.5	Ambient Temperature	300°K	.075 x .50 x 300 =	11
erage Atmospheric Absorption	.021	Ambient Temperature	290	.075 x .50 x .021 x 290 =	.2
alactic Absorption	1.00	Ambient Temperature	10	.075 x .50 x .979 x 10 =	.4
					12°K
		UPPER SIDELOBES, GAIN = 0.075			
mospheric Absorption	.021	Ambient Temperature	290°K	.075 x .021 x 290 =	.4
alactic Absorption	1.00	Ambient Temperature	10	.075 x .979 x 10 =	.8
					1°K
			LOSS	.03 x 300 = 9°K	
			Total		147°K
For a second example take the same antenna pointed up at a clear sky.					
		MAIN BEAM AND UPPER LOBES, GAIN .82 + .075 = .895			
mospheric Absorption	.021	Ambient Temperature	290°K	.895 x .021 x 290 =	6
alactic Absorption	1.00	Ambient Temperature	10	.895 x .979 x 10 =	9
					15°K
		LOWER LOBES, GAIN .075			
Absorption	.50	Ambient Temperature	300°K	.075 x .50 x 300 =	11
mospheric Absorption	.021	Ambient Temperature	290	.075 x .50 x .021 x 290 =	.2
alactic Absorption	1.00	Ambient Temperature	10	.075 x .50 x .979 x 10 =	.4
					12°K
			LOSS	.03 x 300 = 9°K	
			Total		36°K

This approach has been based upon the Fraunhofer (far field) pattern of the antenna. Because many strong noise sources, e.g., sea or land, may be in the antenna near field, for more precise results the near field gain should be used. This is especially true of sidelobe noise since the sidelobe amplitude ratio may be appreciably smaller close to the antenna than in the far field region.

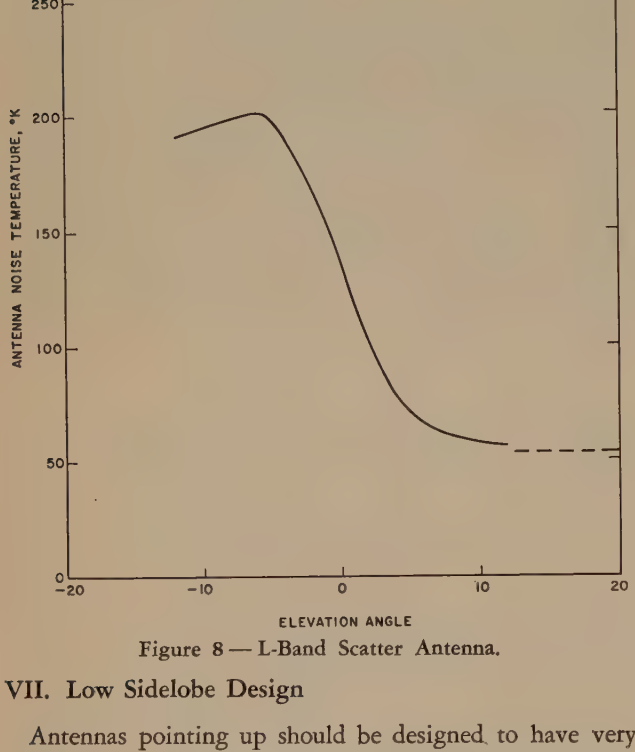


Figure 8 — L-Band Scatter Antenna.

VII. Low Sidelobe Design

Antennas pointing up should be designed to have very low sidelobes. Low sidelobe designs such as Taylor aperture distributions[13] are of value here. Taylor optimum narrow beam low side designs for circular apertures have just been computed.[14] Extreme care must be exercised to reduce feed blockage, feed spillover, and other sidelobe raising effects. Sighting should be high and clear of reflecting buildings, trucks, tanks, etc. Those antennas that must point in the vicinity of land or sea, such as radar and communications antennas, should have an asymmetrical beam design: sharp main beam drop off and very low sidelobes below the horizon, perhaps at the expense of beam skirt and sidelobes above the horizon; see Figure 9. Synthesis techniques for producing skewed beams for optimizing both upper and lower sidelobes are now being developed. A technique being considered by others is that of covering up the ground with a metal sheet to reduce back lobe ground noise (sky noise thereby incurred is of lower temperature). However, the antenna near field may interact with the metal sheet to produce large sidelobes. Narrow beam antennas and elevation angles near vertical would reduce this effect.

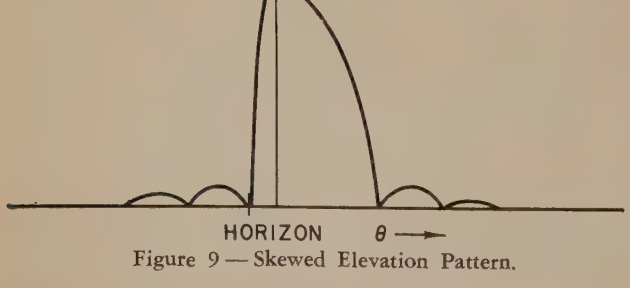
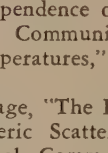


Figure 9 — Skewed Elevation Pattern.

Another problem is the effective noise capture area of a planar array such as a dipole or slot array. At the design frequency the effective area is just that of a dish but at other wavelengths the element capture area changes.

VIII. Conclusions

It has been shown that with the new low noise microwave amplifiers, the noise transduced by the antenna is a limiting factor, and that the absolute system sensitivity is approximately proportional to the antenna effective noise temperature. Typical antenna temperatures for land and sea beams are 150°K; clear sky temperatures at S-band are about 40°K, the floor seems to be around 30°K produced by very low sidelobe designs, and by careful shaping of the main beam to avoid strong noise sources such as sea. Cooling of the feed structure will be valuable only in a few radio astronomy cases where the target is a clear sky, and where actual sidelobes are 25 db or more down.



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Discussions with Elio Sion, C. A. Greene, and H. R. Senf of Hughes are acknowledged with pleasure.

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In previous issues of this journal, much has been said about the Smith Diagram, one of the preferred graphical ethods of solving microwave network problems. Such graphical methods may not only give moderately accurate quan- tative results, but they may provide a good measure of understanding as regards the processes that go on inside the veral components of the network. A few simple examples of practice were cited, but there were left for this and the llowing article some more-involved cases. For the most part, the present examples are not new but are moderately familiar amples of modern microwave technique. They are presented here partly with a view toward alternate views of old ideas nd partly with a view to supplying the student reader with further exercises in the analysis network problems. It is oped that he will ultimately pass on to problems of his own origin and possibly by good fortune to networks that are th novel and useful. One very useful microwave network used in the past is built around waveguide junctions or anches.

GRAPHICAL ANALYSIS OF MICROWAVE COMPONENTS

ART I

George C. Southworth

Waveguide Junctions

When an ordinary two-wire transission line is operated at low frequencies and it feeds power into veral branch lines, its load may be lculated readily from a knowledge the characteristics of the branch nes and their respective loads. At e low frequencies here assumed, e shape or form of the junction tween the main line and its anches is of minor importance. In ntrast, when a waveguide transission line divides into several anches, the load is not only a funcon of the characteristics of the anches, but it may be materially fected by the geometry of the junction itself. That is, two branch uides and their loads when conected to the main guide through a -shaped junction will present an preciably different load than when nnected through a Y-shaped junction. Because junctions play an imrtant part in waveguide technique, is desirable that their characterics be examined.

Types of Junctions

In order to meet the more important requirements of branching, certain standard junctions have been dopted. Figure 1 shows a few possible forms applicable particularly rectangular guides. The dominant E_{10} wave is assumed throughout. ertain of these forms have found nsiderable practical use and will discussed at some length. Others are presented merely as interesting possibilities.

One of the simpler methods of producing a branch in a waveguide is illustrated in Figure 1(a). In this case, we assume that wavepower in the dominant mode is arriving from the left. A very thin conducting septum, *P*, first divides the main guide into two parallel guides, 1 and 2, each having the same *a* dimension but different *b* dimensions, such that $b_1 + b_2 = b$. It can be shown that

$$\frac{K_1}{K} = \frac{b_1}{b} \quad \text{and} \quad \frac{K_2}{K} = \frac{b_2}{b} \qquad (1)$$

and

$$K = K_1 + K_2 \qquad (2)$$

If the two parallel guides are match-terminated and the plate *P* is thin, there will be no appreciable reflection, and the incident power will divide between the two branches in proportions b_1/b *and* b_2/b. These principles may be extended to cover the division of power among more than two guides. After the power has been properly divided we may add reflectionless bends and carry the divided power to widely separated points as suggested by the dotted lines in Figure 1(a). For the particular conditions here assumed, this junction is essentially reflectionless.

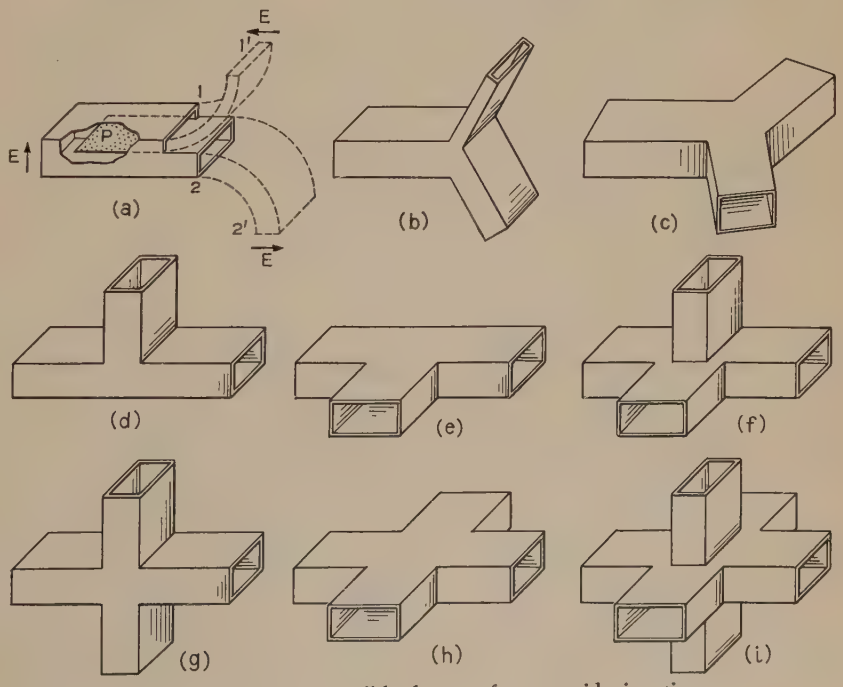


Figure 1 — Some possible forms of waveguide junctions.

If, instead of adding bends, the angle between the two parallel guides formed by plate P in Figure 1(a) is increased progressively, ultimately a configuration will be reached that may be represented by Figure 1(b). It is of special interest that whereas the characteristic impedances of the respective branches may be the same as before and the transmitted power may divide between the two branches in substantially the same proportions as before, there may be present in the main guide an appreciable standing wave. If the angular separation is increased still further, perhaps to the point where the external angle is 180 degrees, the standing wave may be very substantial indeed, and the junction will be far from reflectionless. It would appear, therefore, that there is associated with a branch of this kind, a component discontinuity associated with the impedances which it joins and another that is associated with its geometry. The latter will be referred to below as a *geometrical discontinuity.*

Like other discontinuities in waveguides, that presented by a junction may be compared with an equivalent network placed across a conventional transmission line, and useful analyses may be made on that basis. For a three-arm junction the equivalent network has six terminals. By placing a known impedor, perhaps a piston in this case, in one arm, it becomes the more conventional four-terminal network. Measurements made with pistons located at special positions in each of the arms make it possible to evaluate the various constants of the equivalent circuit.

There are shown in Figures 2 to 5, inclusive, four typical waveguide branches together with their respective equivalent networks. Since the arms of the various branches may be comparable in length to the wavelength and since, therefore, the reactance presented by an element, such as a piston, depends on the distance from which it is viewed, suitable reference planes should be adopted. In the above-mentioned figures, these reference planes are shown as dotted lines. More specifically, if the distance, along an arm, from a piston to its near-by reference plane is a half wave ($\lambda g/2$), we may assume that the arm and its corresponding terminals in the equivalent network are "shorted" at the reference plane. If the distance is a quarter wave, it is open. The behavior

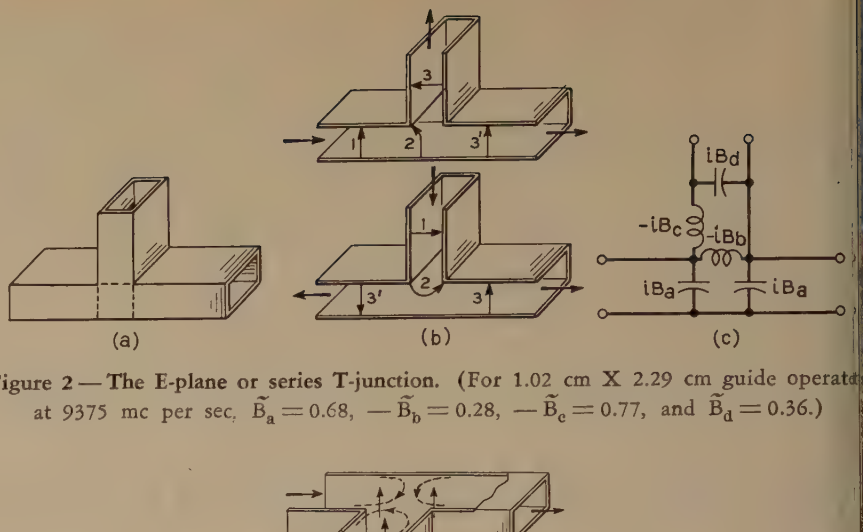


Figure 2 — The E-plane or series T-junction. (For 1.02 cm X 2.29 cm guide operated at 9375 mc per sec, $\tilde{B}_a = 0.68$, $-\tilde{B}_b = 0.28$, $-\tilde{B}_c = 0.77$, and $\tilde{B}_d = 0.36$.)

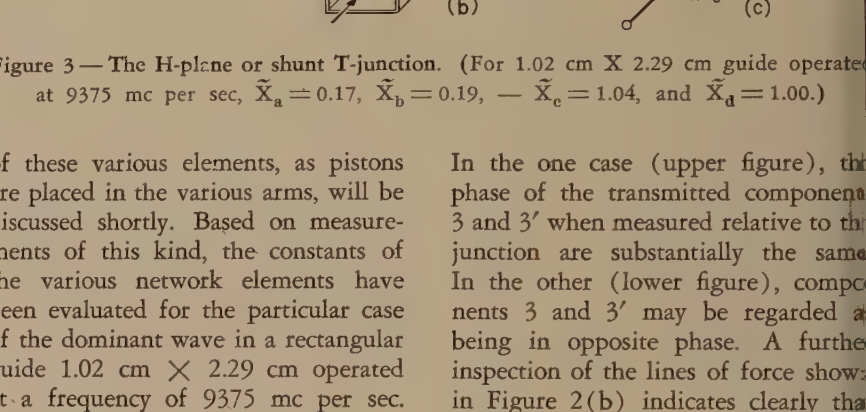


Figure 3 — The H-plane or shunt T-junction. (For 1.02 cm X 2.29 cm guide operated at 9375 mc per sec, $\tilde{X}_a = 0.17$, $\tilde{X}_b = 0.19$, $-\tilde{X}_c = 1.04$, and $\tilde{X}_d = 1.00$.)

of these various elements, as pistons are placed in the various arms, will be discussed shortly. Based on measurements of this kind, the constants of the various network elements have been evaluated for the particular case of the dominant wave in a rectangular guide 1.02 cm × 2.29 cm operated at a frequency of 9375 mc per sec. These particular constants appear in the captions to Figures 2 to 5, inclusive.[1]

Two very common forms of waveguide junctions are shown in Figures 2 and 3. Both are right-angle or tee-arrangements. They differ only with regard to the plane in which the branch lies. Because in the first case, all three arms lie in the electric plane of the dominant wave, it is known as an *E-plane tee.* For similar reasons, the second is known as an *H-plane tee.* Referring particularly to Figure 2(b), it will be observed that two rather different cases of transmission are possible, depending on the particular arms of the junction into which power is introduced. This may be made more evident by comparing the two illustrations. In either case, a representative line of electric force of the wavefront shown as occupying successive positions 1 and 2 may be severed, during transmission, as in 2, to form in the branches two lines of force designated respectively by 3 and 3′. In the one case (upper figure), th phase of the transmitted component 3 and 3′ when measured relative to th junction are substantially the same In the other (lower figure), compo nents 3 and 3′ may be regarded a being in opposite phase. A furthe inspection of the lines of force show in Figure 2(b) indicates clearly tha not only are there two possible case of transmission as regards the directio of propagation, but the two case differ as regards symmetry. It shoul not be surprising, therefore, if th tee should appear as a somewhat dif ferent discontinuity when viewed fro different arms. This is indeed true a standing wave measurements show.

If there were no side walls to th guide shown in Figure 2, the top an bottom plates would constitute tw parallel conductors of an ordinar transmission line. Then the two line of the branch would be in series. Be cause of this analog, this arrangemen is sometimes known as a *series branch.*

Figure 3 shows a right-angle junc tion in which all three arms lie in th magnetic plane. In contrast with th previous case, it will be seen that her it is the lines of magnetic force tha are severed by the branch and, fo reasons previously noted, this type o junction is sometimes known as *parallel-tee* or *shunt-tee.* Again ther are two possible cases of transmissio

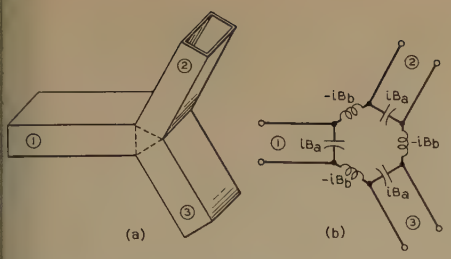


Figure 4 — The symmetric or 120-degree form of E-plane junction. (For 1.02 cm X 2.29 cm guide operated at 9375 mc per sec, $\tilde{B}_a = 0.29$ and $-\tilde{B}_b = 4.68$.)

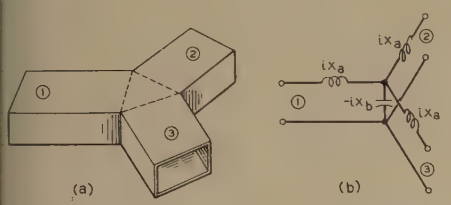


Figure 5 — The symmetric or 120-degree form of H-plane junction. (For 1.02 cm X 2.29 cm guide operated at 9375 mc per sec, $\tilde{X}_a = 1.07$ and $-\tilde{X}_b = 0.56$.)

through the junction, and again the apparent discontinuities for the two connections are quite different.

The symmetrical operation of the right-angle tee as illustrated by the lower part of Figures 2(b) and 3(b) may suggest a 120 degree arrangement, such that the branch is symmetrical regardless of the particular arm through which it is viewed. The corresponding E-plane and H-plane cases are illustrated, respectively, by Figures 4 and 5. Although these symmetrical arrangements, when properly terminated, provide an equal division of power, they are by no means reflectionless. It will be observed that, even though there were no geometrical discontinuity at the junction, the characteristic admittances for the case where all arms are identical are such as to lead to a normalized impedance ratio of two, as viewed from any particular arm. The standing wave ratio would therefore be 6 db. Experience shows that the presence of the geometrical discontinuity adds a small reactive term. Standing wave ratios of 3 db are typical of 120-degree matched-terminated branches.

Junctions as Reactors

In most of the previous discussion, it is assumed that power is introduced into one of the three arms of a junction, while the others are matched-terminated. Although this case is important, there is considerable practical interest in the case in which one of the arms contains a pure reactance, such as might be approximated by a short piece of pipe containing a tightly fitting metal piston. The junction may then serve either as a bend or as a filter element, depending on the particular proportions chosen.

To illustrate further, there are shown in longitudinal section in the lower part of Figure 6 an E-plane tee together with a piston occupying three possible arms. The more important properties of this arrangement may be calculated by conventional methods assuming the equivalent network shown in Figure 2(c). However, it will be more instructive in the present case to trace on an admittance diagram certain experimental points based on actual measurements of conductance and susceptance looking into the tee from the three directions indicated by the double arrows in Figures 6(a), (b), and (c), as the piston is moved through a succession of positions. The piston distances are measured relative to the nearer wall of the intersecting guide, while the point at which observations are made is assumed to be an integral number of half waves from the centerline of the intersecting guides. The locus of points for each case is essentially a circle. The data are typical of an E-plane tee made up of 6.02 cm $\times$ 2.29 cm waveguide operated at a frequency of perhaps 9400 mc per sec. The actual piston distances L/λ are regarded as of secondary interest. Hence only a few are shown.

Several important conclusions may be drawn from Figure 6. Only in Case *b* does the locus pass close to the coordinates $1 + i0$ (match). Hence, it is only under this circumstance that the arrangement is electrically smooth. This, it will be observed, occurs when the piston distance (L/λ) is 0.45. Allowing for a small amount of fringing at the junction, one may consider this distance to be the nominal half wave that, in effect, translates the conducting piston to the wall of the guide. Hence, at this point, the side arm is effectively shorted, and the

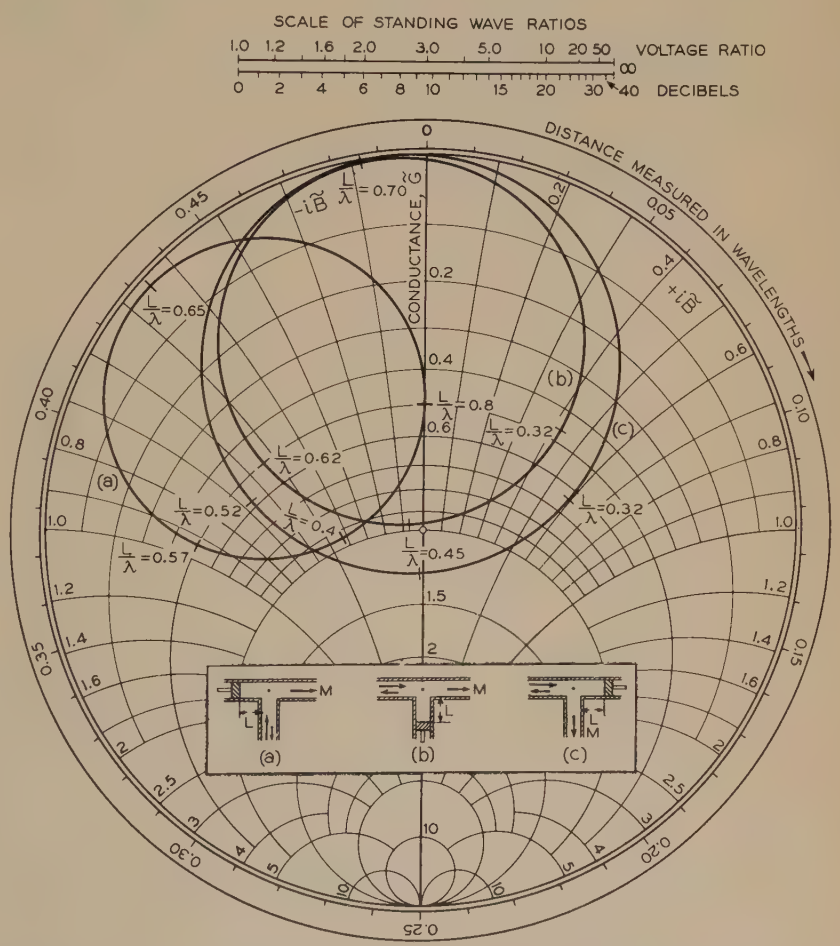


Figure 6 — Loci of possible admittances presented by an E-plane T-junction with a piston located in one of each of three arms illustrated. Admittances are referred to point (dot) shown at the intersection.

result is almost as though no side arm existed. For this case, the insertion loss is negligible. Increasing the piston distance corresponds to a clockwise motion around circle *b*. At a point near where the piston distance is 0.62λ, the apparent normalized susceptance is optimum ($\tilde{B} = i0.55$), after which both the conductance and the susceptance approach zero. At this position, the standing wave ratio is very large, and very little power is transmitted through the main guide. Insertion losses of about 35 db are representative. In the region where the conductance is small and no power is transmitted, it is convenient to regard that portion of the main guide that lies to the right of the junction as effectively cut off and removed. It may be noted in passing that, under this circumstance, the branch has certain of the characteristics of a band-rejection filter as compared with the first point on the circle where the device behaved somewhat as a band-pass filter.

That the location of circle *b* is not quite symmetrical with respect to the conductance axis merely reflects certain conditions of the experiment by which the original data were taken. It will be remembered that the apparent admittance of a given discontinuity may assume different values when viewed at various distances along a line. In view of this, it will be seen that increasing by perhaps 0.015λ the distance along the guide at which observations were made would have rotated circle *b* into a symmetrical position. Alternatively, one may say that the result is as though reflection had taken place from a point slightly to the right of the reference points in Figure 6(b). This may be regarded as a kind of fringing.

Circle *c* of Figure 6 shows that there is no piston adjustment at which the arrangement is electrically smooth. Even at the most favorable condition, a standing wave ratio of perhaps 2 db prevails. At this point, the mismatch appears as a nearly pure conductance greater than characteristic admittance. One concludes, therefore, from these data that this arrangement alone could not be used as a smooth bend in a waveguide. For reasons already noted, the slight asymmetry in the location of circle *c* may be corrected by choosing a slightly different datum point along the guide at which observations are made.

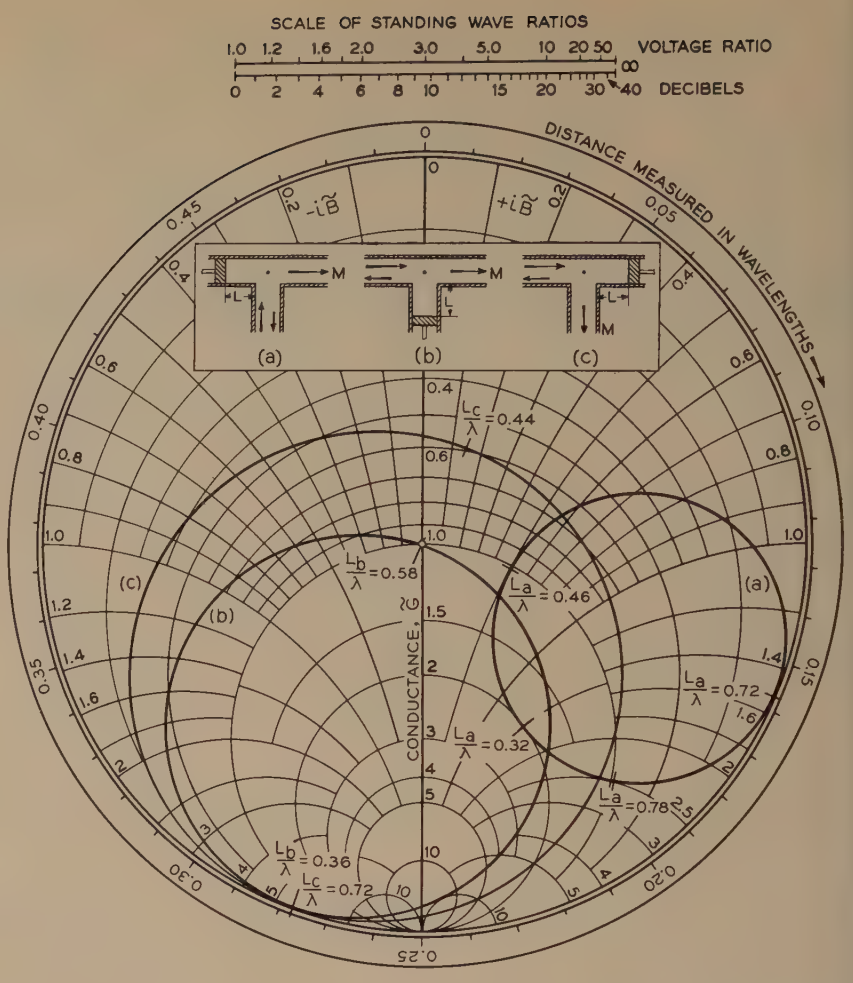


Figure 7 — Loci of possible admittances presented by an H-plane T-junction with a piston located in one of each of three arms as illustrated. Admittances are referred to a point (dot) in the intersection.

Referring finally to Case *a*, it will be seen that the locus of admittances lies entirely in the domain of negative susceptances and normalized conductances of less than unity. At one point only is the admittance a pure conductance. At this point the standing wave ratio is about 6 db. As in the previous case, the minimum standing wave ratio is about 2 db.

For purposes of comparison, there are shown in Figure 7 the corresponding admittance data for an *H*-plane tee. As compared with the previous case, the loci of admittances are now shifted into a region of relatively high values. Again it is only the symmetrical arrangement, Case *b*, that may be made electrically smooth (insertion loss negligible).

This time the anti-resonant condition is one where the transverse conductance is very high. The result is almost as though the piston had been transferred from the stub to the main guide. Effectively, the main guide has been shorted. Insertion losses of about 47 db have been measured. Referring to Case *a*, it will be seen that even with the most favorable adjustment for match, a standing wave ratio of about 4.3 db prevails. For Case *c*, the corresponding standing wave ratio is about 5.0 db. In contrast with Case *a* for the *E*-plane tee which gave rise in general to negative susceptances, Case *a* for the *H*-plane tee gives rise to positive susceptances. In the second instance, the minimum occurs near the point $1 + i0.5$.

It will be evident from Figure 8 that, when the 120-degree branch is operated under the conditions just discussed, all three possible cases are identical. In each, there is a piston position for which the junction appears electrically smooth, thereby making it possible for it to function either

as a smooth 60-degree bend or as a form of bandpass filter. In each case also, there is a piston position for which a very high standing wave may be set up. In this instance, the device may function as a form of band-elimination filter. As before, the respective *E*-plane and *H*-plane junctions are essentially different.[3]

Waveguide Stub Tuners

Referring to Figures 6(b) and 7(b), it will be seen that, by means of apparatus located outside a main guide, we may produce inside a variety of reactance (or susceptance) effects. These range from nearly zero to nearly infinity. The apparatus for bringing this about is referred to as a waveguide stub tuner. It consists simply of a piston in a short piece of pipe together with the necessary junction.

One possible application of this principle could be that of a switch for turning on and off power flowing through a main guide. The operation from off to on would be merely that of displacing the piston a quarter wave. In a variation of this method the piston is replaced by a gas-discharge device, which when "fired" is a good conductor and when "cold" is a good insulator. By this means, the piston, here assumed, effectively oscillates back and forth many times per second to admit or reject power. Similar results may be obtained by the use of ferrite devices.

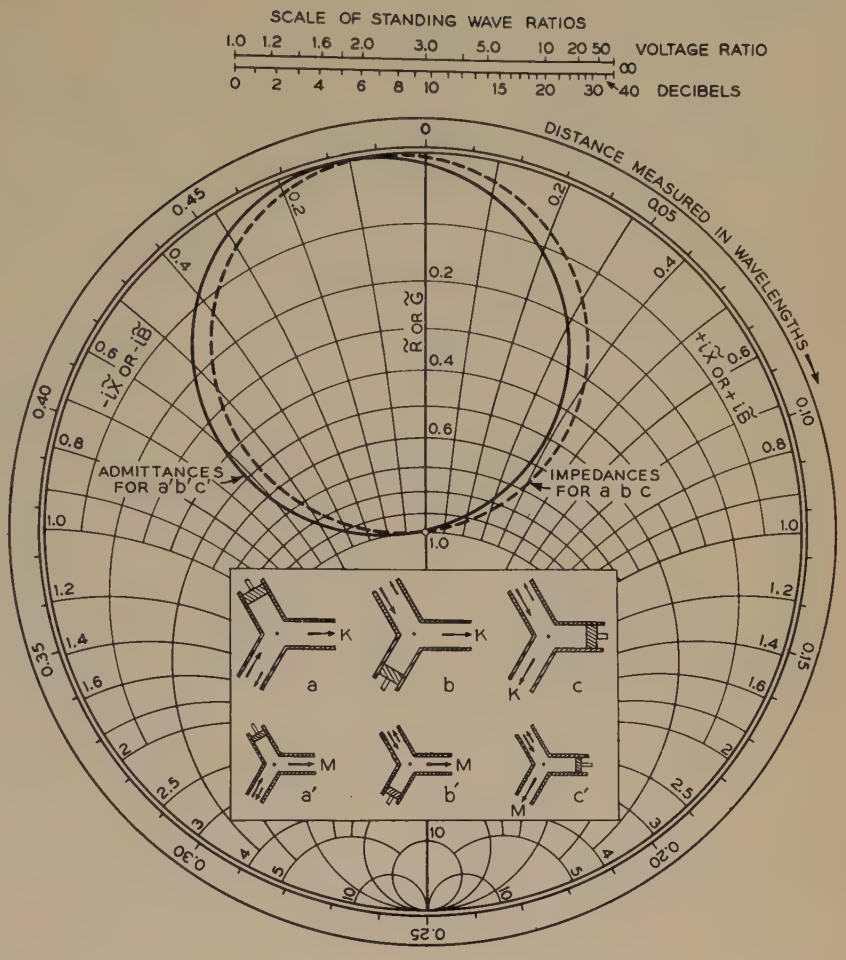


Figure 8 — Loci of admittances and impedances for 120-degree Y-junctions referred to point (dot) in the intersection.

Footnotes

1. The equivalent networks in Figures 2 to 5, inclusive, were taken from reports 41-1-23-45 and 43-2-7-44 of the MIT Radiation Laboratory. These reports were prepared under the direction of Drs. E. M. Purcell and G. E. Uhlenbeck, respectively.
2. In the vicinity of the junctions such as illustrated in Figure 2, rather complicated field distributions prevail. These may be resolved by Huygens-construction methods, with results indicating that there may be generated in the vicinity of the junction certain of the higher-order waves. However, if the dimensions are such that only the dominant mode can be supported, such waves may not be propagated over any appreciable distance. Observations made a short distance from the junction in these smaller guides show that the dominant mode is soon restored both in the main guide and in the side arm.
3. Though the two loci of Figure 4 may appear, at first sight, similar, they are really very different since one relates to admittances while the other relates to impedances. If the impedances were converted into equivalent admittances, the corresponding circle would be translated to a diametrically opposite position on the diagram.

We are grateful to the D. Van Nostrand Co., Inc. for the use of material in this article drawn from the book, PRINCIPLES AND APPLICATIONS OF WAVEGUIDE TRANSMISSION, authored by Dr. George C. Southworth; and to the Bell Telephone Laboratories for the use of their material.

RAPID MEASUREMENT OF MICROWAVE CAVITY PARAMETERS

Richard J. Mohr

FXR, Inc.

ABSTRACT

A measurement technique for the rapid determination of microwave cavity parameters is described. The technique is first evolved for the condition where the cavity under test terminates a transmission line. Then it is shown that the technique can be made applicable to the conditions of series and shunt connected cavities.

Among the more frequent microwave measurements are those performed to determine the properties of resonant cavities—bandwidth, VSWR, and loaded and unloaded Q. For cavities which terminate a transmission line, the two most frequently used measuring techniques are the VSWR and the phase shift measurement methods. Both techniques require a relatively large amount of experimental data which must be put in graphical form before the cavity parameters can be determined. A simpler and speedier technique which may be performed by relatively unskilled technical personnel will be described. Its application to reaction type cavities will also be shown.

General Considerations

The validity of the technique is based on two important concepts.

1. In the vicinity of resonance a microwave cavity can be represented by an equivalent lumped resonant circuit connected at suitable reference terminals on the transmission line.

2. Small changes in the frequency at which measurements are made are equivalent to equal, but opposite changes in the resonant frequency of the cavity under test (insofar as their effect on cavity impedance is concerned).

In accordance with the first concept it will be shown that, once the reference terminals for the cavity are found, it is possible to measure microwave cavities by a method exactly analogous to that used on lumped resonant circuits.

The second concept offers an expedient which is frequently used in microwave cavity measurements. In making the measurements, a fixed frequency source is used while the resonance is explored by tuning the cavity. This is a convenience since, for the accuracy required for extremely narrow band measurements, it is usually easier to vary the cavity tuning than the oscillator frequency. It is only necessary that the tuning rate of the cavity be known. This is usually known quite accurately from theory or else it may be determined experimentally.

A further convenience afforded by this concept is that it allows the choice of reference terminals which may be located as far from the cavity as is desirable. This is a result of the characteristic half-wave repetition of impedance on a uniform transmission line. If the frequency instead of the cavity tuning is varied, the lumped equivalent concept is accurate only for reference terminals close to the cavity.

Derivation of Technique

The measurement set-up is shown in Figure 1. The pad is employed to provide a good match as seen looking to the left from the cavity. The detecting element in the sliding probe is operated in its square-law region. In Figure 2, the equivalent circuit of Figure 1, the generator is replaced by its current source equivalent. G_0 is equal to the characteristic admittance of the transmission line. The sliding probe and VSWR indicator are replaced with the infinite impedance voltmeter shown. The cavity is replaced at its reference terminals AA' by its lumped equivalent circuit. Since terminals AA' are not accessible in this set-up, it will be necessary to use terminals which are an integral number of half wavelengths away from AA'.

When the cavity is tuned far off resonance, it acts as a short circuit at

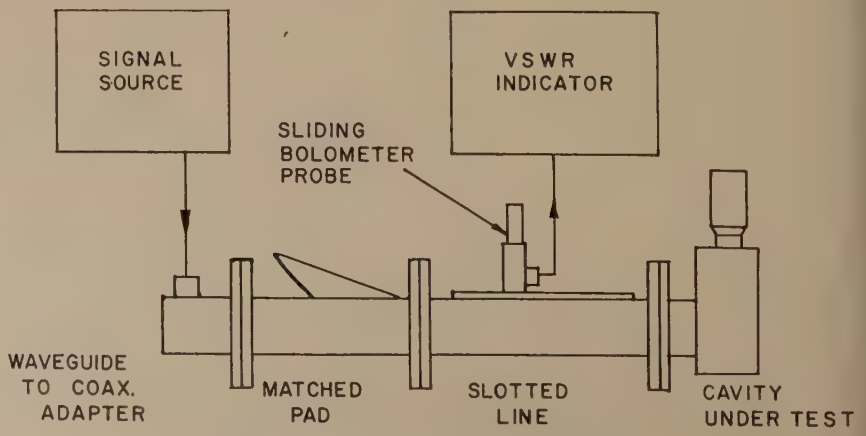


Figure 1 — Set-up for cavity measurements.

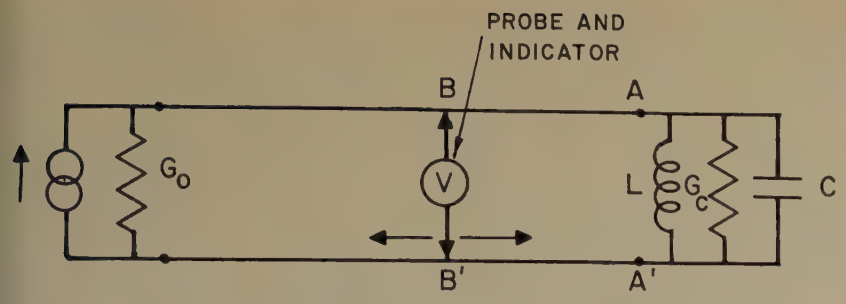
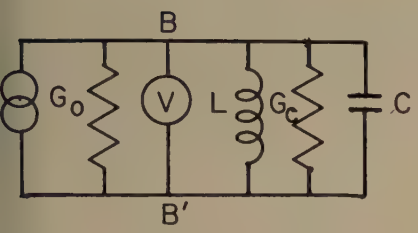


Figure 2 — Equivalent circuit for set-up of Figure 1.



ure 3 — Simplified equivalent circuit or set-up of Figure 1.

A'. Therefore, with the cavity de-ed, any minimum position observed the slotted section will be an in-ral number of half wavelengths m AA' and will serve as reference minals.

The circuit of Figure 2 can now reduced to that of Figure 3. Term-ls BB' are the reference terminals be used. This is an exact equivalent the circuit used for the measure-nt of Q at low frequencies. Reso-nt tuning of the cavity is indicated maximum voltage across BB'. Also, 3 DB bandwidth points are found the cavity tuning position where voltage at BB' drops to .707 of resonant voltage. Bandwidth and ded Q are calculated as follows:

$$\text{Bandwidth} = F_2 - F_1 \qquad (1)$$

$$Q_1 = \frac{F_o}{F_2 - F_1} \qquad (2)$$

F_2 = High frequency 3 DB point
F_1 = Low frequency 3 DB point
F_o = Resonant Frequency
Q_1 = Loaded Q

A simple analysis of Figure 3 shows t

$$Q_o = (1 + \frac{G_o}{G_c})\ Q_1 \qquad (3)$$

Q_o = Unloaded Q

From Figure 2, $\frac{G_o}{G_c}$ must be equal either the resonant VSWR of the ity or the reciprocal of this VSWR. he terminals BB' are at a maximum ition on the standing wave pattern n $G_c < G_o$ and the ratio G_o/G_c is al to the resonant VSWR. Conversely if BB' is at a minimum position on the standing wave pattern then $G_c > G_o$ and the ratio G_o/G_c is equal to the reciprocal of the resonant VSWR. The measurement procedure may now be outlined as follows:

Measurement Procedure for Cavities Terminating a Transmission Line

1. With the set-up of Figure 1, completely detune the cavity.
2. Move the probe to a minimum position as indicated by the VSWR indicator.
3. Tune the cavity to resonance as indicated by a maximum reading on the VSWR indicator.
4. Observe the cavity tuning position on both sides of the resonant position at which the reading on the VSWR indicator falls 3 DB from its resonant reading. Record these tuning positions as F_2 and F_1.
5. With the cavity back on resonance, observe, by moving the probe, whether the probe is at a maximum or minimum position of the standing wave pattern.* If it is at a maximum position, note that G_o/G_c = VSWR. If it is at a minimum position, note that $G_o/G_c = 1/\text{VSWR}$.
6. Measure the VSWR.
7. Calculate the desired parameters from equations 1, 2, 3.

*NOTE: If probe is found to be at neither a maximum nor minimum position a condition of generator mismatch exists. This is discussed below.

For the measurement of narrow bandwidths, the graduations on the cavity dial may not be fine enough to measure the 3 DB bandwidth accurately. For such cases a larger bandwidth such as the 6 DB or 10 DB bandwidth may be measured and the 3 DB bandwidth calculated from it as follows:

$$B\ (3\ DB) = \frac{B_r}{\sqrt{R-1}} \qquad (4)$$

B (3 DB) = 3 DB bandwidth
B_r = Measured bandwidth between the R points.
R = Particular power ratio used. (2 for 3 DB bandwidth, 4 for 6 DB bandwidth.)

For example, the 6 DB and 10 DB bandwidths are seen to be 1.732 and 3 times the 3 DB bandwidth respectively.

A word of precaution is necessary in these measurements. It has been assumed throughout that the generator is matched to the line. If it is not matched, the measurement of Q_1 may be in error because of the resistive component of the generator admittance being different from the loading in the matched conditions. Further, the cavity when tuned as in step 3 above will be off resonance by an amount to just cancel the susceptance of the generator at the reference terminals. Hence the VSWR measured will not be the resonant VSWR. Fortunately, both errors are dependent on the phase of the generator impedance in different ways such that when the error in Q_1 is greatest, the error in VSWR is negligible and vice versa. Hence Q_o which is determined from Q_1 and resonant VSWR will not be in error by more than the maximum error for either. For a small generator VSWR, r, the maximum error in these measurements will be approximately $(r-1) \times 100\%$. A generator VSWR of 1.05 will then cause a maximum error of about 5%.

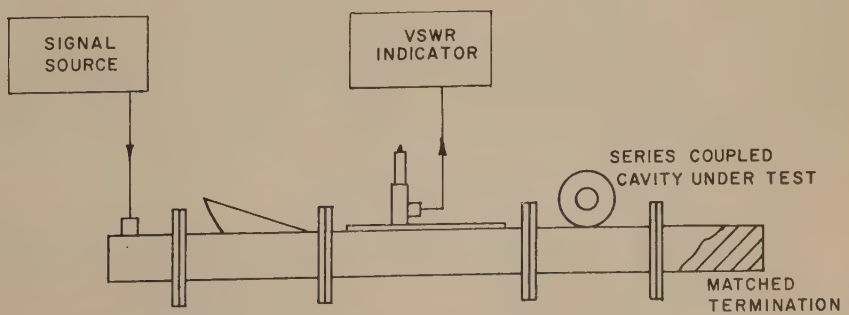


Figure 4 — Set-up for measurement of series connected cavity.

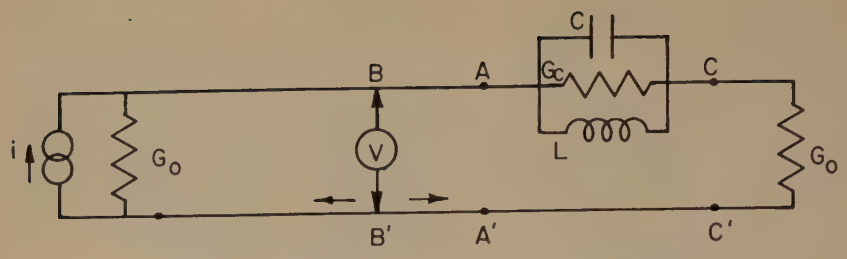


Figure 5 — Equivalent circuit of set-up in Figure 4.

Application to Reaction Type Cavities

The measurement technique may be adapted to reaction type cavities. Consider the set-up in Figure 4. Assume it is desired to measure the unloaded Q of this series coupled cavity. In order to apply the technique described above, it will first be necessary to reduce the situation to that of Figure 1. From Figure 5, the equivalent circuit of Figure 4, it is seen that this circuit may be reduced to the situation of a cavity terminating a line if a short circuit is placed at CC′, or any integral number of half wavelengths to the right of CC′, as in Figure 6. To determine the correct location of the short, it is first observed from Figure 5 that with the cavity tuned to resonance, the impedance across AA′ is real and a maximum. Consequently, any point such as BB′, a number of half wavelengths to the left of AA′, will serve as reference terminals for the cavity. It is next observed that with the cavity at resonance, the impedance across AA′ will be minimized with a short at CC′, as in Figure 6. The procedure for setting up the system may now be outlined as follows:

Measurement Procedure for Reaction Type Cavities

1. With the set-up as in Figure 4, tune the cavity to resonance as indicated by a maximum VSWR.

2. Move the probe to a maximum** position on the VSWR pattern.

3. Remove the matched termination and replace it with a sliding short.

4. Adjust the short position for a minimum reading on the VSWR indicator.

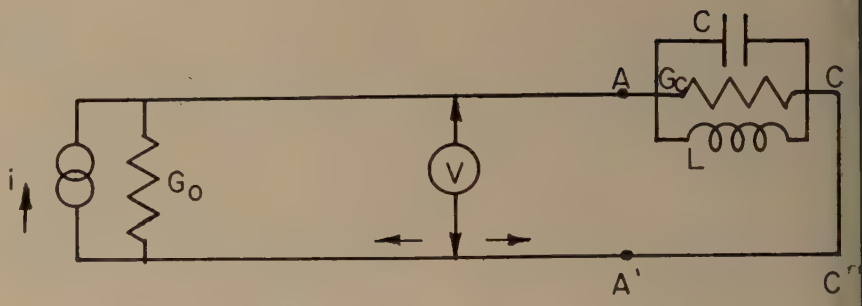


Figure 6 — Series connected cavity terminating a transmission line.

5. Perform steps 1—7 of the measurement technique for cavities terminating a transmission line.

Although a shunt connected cavity behaves as a low shunt impedance at resonance, the set-up procedure for measuring it is identical to that described for a series connected cavity. This is due to the fact that a shunt connected series resonant circuit on a transmission line appears as a series connected shunt resonant circuit at odd numbers of quarter wavelengths toward the generator. Thus it is not even necessary to know whether the cavity is shunt or series connected to apply this technique.

A bibliography is included which may be of use to the reader seeking more information on cavity measurement techniques.

**NOTE: The maximum position referred to in step 2 may sometimes be too broad to locate accurately. As a result, the short position in step 4 will also be incorrect. To correct the situation, after step 4, the short position and cavity tuning should be adjusted for minimum VSWR before proceeding with step 5.

Acknowledgment

The author extends thanks to M
John Ebert, Vice-President, Micr
wave Dept., FXR, Inc., for his helpf
suggestions in preparing this paper.

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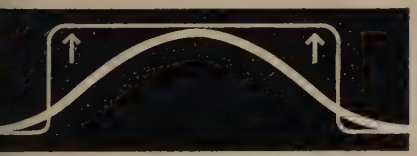

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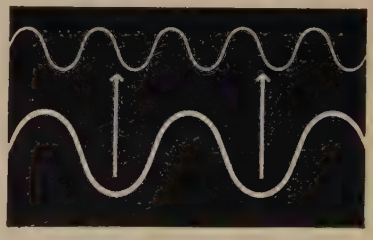

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NEW PRODUCTS

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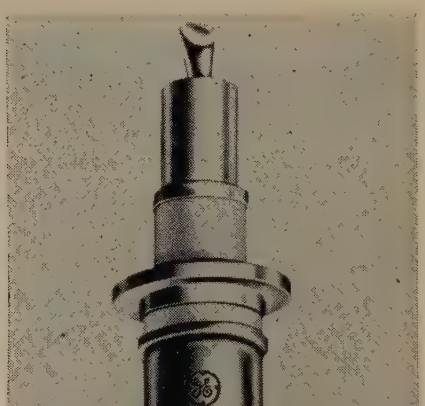

An improved general purpose, high-mu lighthouse triode designed for use in grounded-grid service as a radio-frequency amplifier, oscillator, or frequency multiplier, is now available from General Electric's Power Tube Department, Schenectady, N.Y.

The metal-ceramic GL-6771 tube is particularly suited for use as a continuous-wave oscillator to frequencies as high as 4000 Mc. As an oscillator, 200-300 milliwatts of non-squegging CW power may be obtained. As a frequency doubler to 1000 megacycles, 2 watts of output power may be obtained with only 300 milliwatts of drive power.

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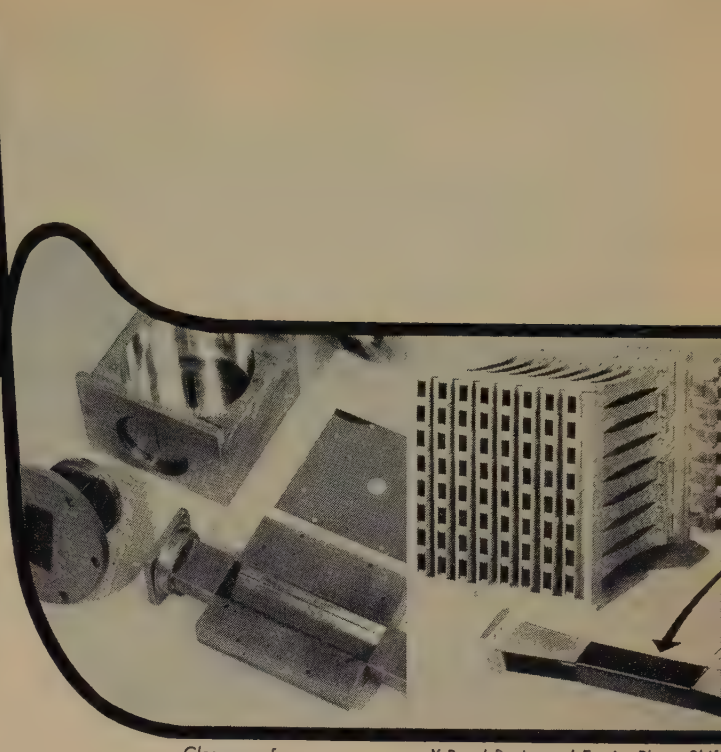

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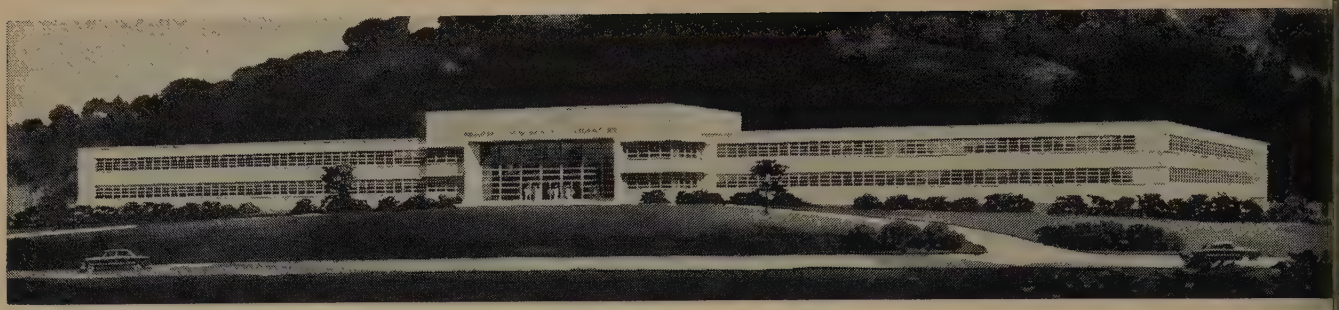

Airborne's New Melville, L.I. plant

AIRBORNE INSTRUMENTS LABORATORY — A Division of Cutler-Hammer, Inc.

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BOX SCORE

NAME: Airborne Instruments Laboratory, (A Division of Cutler-Hammer, Inc.)

LOCATION: Headquarters at Garden City, Long Island, New York. Plants located in several Long Island communities.*

PRODUCTS: R & D and production in the fields of microwave, machine tool controls, radio astronomy, air traffic control, medical electronics, electronic reconnaissance and radar.

HIGHLIGHTS: This 14-year old company started as military research and development specialists in radar and ECM; now has a variety of commercial and military products in production, conducts research on over 100 projects in fields including radar, ECM, medical electronics, air traffic control, radio astronomy.

*We have been advised that AIL has completed negotiations with the Fairchild Engine Division for the purchase of that company's facility in Deer Park, L.I. This facility (493,000 sq. ft. on a 101 acre plot) will, by the year's end, consolidate all of AIL's production, engineering and administration facilities, with the exception of those technical departments which, by that time, will have been established at AIL's Melville Laboratories.

EASY ROAD TO RECOGNITION

AIL got to be an R & D leader the easy way: they virtually *started* there. Most small electronics firms start with one or two skilled engineers, an idea for a new product or know-how in a particular field, and a little capital. But AIL, formed at the end of World War II, enlisted whole teams of scientists and engineers from the Airborne Instruments Laboratory at Columbia and the OSRD Laboratories of Harvard and MIT. Thus, Airborne had recognition at its inception — the recognition already earned by the scientists for their war-time achievements, primarily in the fields of radar and submarine detection devices.

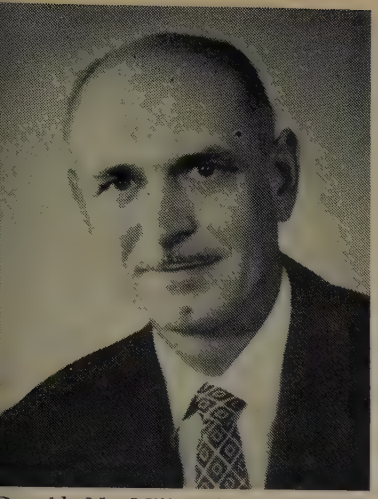
THE WAITING MARKET

With this acceptance, Airborne had no trouble in finding a market for its R & D services. Although Hector Skifter (Airborne's President[1]) would have liked to be able to establish a balance between Government and civilian contracts, industry was not yet interested in the kind of work AIL was equipped to do. Government contracts for studies in air navigation and electronic countermeasures contented him at the time, but he kept a weather eye for opportunities to branch out into better balanced fields.

BROADENING THE BASE

Early extensions of the company's research activities were, naturally enough, in fields closely related to the original ones, such as tracking and air traffic control radars, microwave equipment, and data processing equipment. In 1949, after four years of operation, the Engineering and Production Division was established so that Airborne could manufacture in quantity the equipment developed

1. Named as Assistant Director for Defense Research and Engineering (Air Defense), with particular responsibility for technical evaluation and integration of defensive weapons systems and planning and supervising the development of new and improved systems, with their control environment, including anti-aircraft and anti-missile missiles and interceptor aircraft, Dr. Skifter is on leave from the position as President of the Airborne Instruments Laboratory, Division of Cutler-Hammer, Inc.



Donald M. Miller, Executive Vice-President, Airborne Instruments Laboratory

Hector R. Skifter, President of Airborne Instruments Laboratory

Philip Ryan, President, Cutler-Hammer Inc.

the Research and Engineering Division. Originally aded by Donald Miller, the division became the responsiity of Orville Dunning when Miller was made Executive P. in 1957.

In recent years the company has taken aggressive steps establish its products in commercial and industrial arkets. This was furthered by the addition of an Apied Research Division under the guidance of Vice Presint Arthur Loughren.

The Applied Research Division, which was formed in ecember 1956, is the youngest of the Laboratory's three erating divisions. Its objective then was to discover new pes of business for Airborne Instruments Laboratory. nce Airborne's merger in May 1958 with Cutler-Hamer, Inc., Applied Research has assumed the further obctive of discovering ways to apply Airborne's electronics ow-how to problems encountered by the parent comny in its multitudinous products line and in its services customers in all types of continuous-process industries.

HE KEY OPERATING DIVISIONS

pplied Research

As implied in its name, the Applied Research Division erates in the realm of research and development; hower, it is research and development directed toward the eation of only those devices for which there are sizable arkets.

Applied Research seeks new business through the deopment of new products that can be manufactured (1) Airborne or by the parent company, or (2) by outside mpanies under patent arrangements with AIL. The Labtory's patent office is therefore as much a part of the vision as are the two operating technical groups — the epartment of Medical and Biological Physics and the dustrial Applications Section.

The Inchworm Motor now in production in AIL's Engiering and Production Division is typical of the equipnt now being developed by the Industrial Applications ction of Applied Research. The Inchworm was developed answer to the requirement for microinch control of the terless grinders in the machine tool industry.

Other current projects in this Section are: (1) a project olving aspects of machine tool automation, and (2) ctronic equipment for the Cutler-Hammer newspaper cker and counter. The Section is also bidding on contracts for the development of data-processing equipment and for process control automation in several industries where Cutler-Hammer electrical controls are recognized as standards of quality engineering.

Medical and Biological Physics a department under the supervision of Walter Tolles (who incidentally is Chairman of the Professional Group on Medical Electronics-IRE) has developed several kinds of electronic equipment which medical researchers find highly valuable. One of these developments is the Cytoanalyzer (see the 1957 year book, Electronics Section of the Encyclopedia Britannica). The Cytoanalyzer, now under clinical evaluation by the American Cancer Society and the National Cancer Institute is expected to speed the time required to determine a microscopic examination, the presence of cancer in human cells. The Cytoanalyzer simulates the visual examination by scanning a smear on a slide electronically, counting and classifying the cells according to nuclear size and density, possible because cancerous cells have larger and denser nuclei than normal ones. It has been estimated that early and regular cytological examinations could reduce the 16,000 annual deaths attributed to uterine cancer by 90 percent. The examination speedup made possible by the Cytoanalyzer makes such extensive examinations considerably more practical.

Engineering and Production

Coming off the assembly line from the two large plants which now house the Engineering and Production Division are Airport Surface Detection Equipment[2] (a K-band

2. ASDE, a radar for ground traffic control was formally turned over to the Civil Aeronautics Administration at dedication ceremonies held at New York's Idlewild Airport in June of 1958. Developed by AIL, this radar provides increased safety, especially during marginal weather, for planes before takeoff and after landing. The new radar scans the complete airport and profiles, for control tower operators, all movement of planes and other vehicles on runways and taxiways. Fully operative in any weather, day and night, the radar antenna picks up objects as small as a man a mile from the tower and pictures them on a scope in the operations office. Particularly valuable at busy airports, and with the advent of jet planes, orders have already been received from the FAA for ten additional equipments to be installed at airports in Washington, Chicago, Boston, Newark, New York, Cleveland, Los Angeles, San Francisco, and Seattle-Tacoma. The USAF, Rome Air Material Area, purchased 5 of these radars in May of this year for installation in military airports.

radar system now installed at New York's Idlewild Airport, and which company officials describe as "one of the highest resolution units in operation"), data processing systems, moving target indicators, track-while-scan radars an assortment of test equipment, "MICROtrol" gauging and automatic control equipment, and "INCHWORM" motors. The aptly-named "INCHWORM" is an intriguing device capable of moving large mechanical loads microinches at a time without backlash or overshoot. Based on an application of magnetostostriction, the motor makes use of the fact that heat-treated nickel will undergo shrinkage in a saturating magnetic field. In an application which serves as a kind of tribute to AIL's engineering genius, the machine tool industry now uses "INCHWORMS" to move objects weighing many hundreds of pounds, with accuracies of about one-fourth the wavelength of green light. (Inchworm has also been given recognition by the 1957 year book of the Encyclopedia Britannica, Electronics Section).

For the Missile Master, first fully operational electronic air defense control system in the U.S., Airborne designed and built the radar tracking and display sub-system for The Martin Company. On eight radar consoles operators detect enemy aircraft and establish and monitor the tracks. Associated equipment contains memory circuits for storing the position, velocity, and height of the planes, and computing circuits for predicting their future positions. For this purpose, Airborne designed a computer which is described as "the largest and most accurate analogue computer ever built in the United States for the tracking of large numbers of airplanes by a single ground station." The computer techniques developed for Missile Master are now being applied to other fields, such as civil air traffic control.

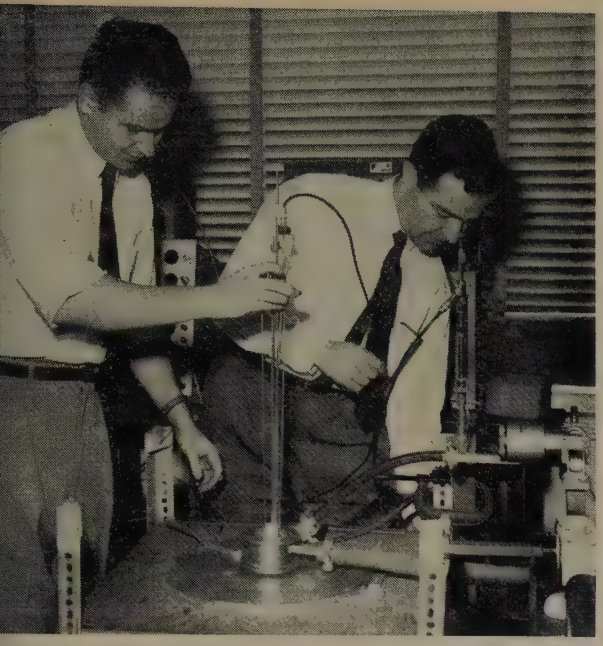
In microwaves, one of the significant contributions made by AIL is in alleviating the problem radar echo from storm clouds and precipitation areas. Since thes echoes sometimes completely obscure the targets, the pro lem was one of serious proportions in both commercial a control and military radars. AIL's approach was to u circular polarization, a method proven feasible by MIT Radiation Lab toward the end of World War II. Th works because a circularly polarized wave with a righ hand rotational sense returns from a spherical rain dro with the opposite polarization and is rejected by the a tenna. When incident upon unsymmetrical targets, suc as aircraft, a distorted elliptical wave returns, and th component with right-hand rotational sense is accepted b the antenna. So successful has AIL been in this wor that the equipment is now installed in some of the majo U.S. airports, including New York, Newark, Bosto Chicago, and Washington, D.C.

Other production items include a line of microwave te equipment for such functions as noise figure indication, a tenna and receiver measurements, and crystal testin MTIs and MTI test sets developed and produced by Ai borne in quantities are now part of the military inventor

Research and Engineering

But it is Vice-President John Dyer's Research and Eng neering Division which has been and still is the backbon of the company. The varied projects in which his peopl are now engaged are so numerous that we can mentio only a few here. Among the most significant are importa contributions to the pressing problems of air traffic co trol, ballistic missile defense system studies, counte countermeasures techniques, reconnaissance systems fo supersonic aircraft, and space vehicle electronic system Some teams of scientists in the division are developin

Personnel of the 35th AAB man tracking consoles which monitor early warning information received by the Missile Master Syste at Fort George G. Meade, Md. This equipment was designed and built by AIL under subcontract with the Martin Co.



Tunable L Band Maser Structure being lowered into the id helium bath during the breadboard development stage. ured are Sy Okwit, Project Engineer and Frank Arams, sultant. (The Maser System has since been packaged and delivered for use by the Department of Defense.)

ite devices and investigating masers and reactance lifiers.

n the fields of masers, ferrites, and reactance amplifiers, 's engineers have achieved notable firsts: an L-band able ruby maser (800-2500 Mc), the first low-loss L- S-band ferrite circulators, and a host of reactance rametric) amplifiers incorporated in such receiving ems as that for the U.S. Signal Corps Diana Moon lar at 400 Mc. A strong support program of analytical experimental work is underway to maintain this leader- in these new fields. In radio astronomy, AIL's equip- nt has provided invaluable aid to researchers in this l; in solar spectrum analysis, measurement of refraction absorption in the atmosphere, in extra-galactic hydro- research. Recently, the first measurements of Jupiter ation at 22 cm were made by Dr. Frank Drake at AO, Green Bank, with AIL equipment.

The titles of other project areas indicate how greatly borne has expanded in its 14 years of operation: human ineering, radio astronomy instrumentation. Vice-Presi- t Dyer, in a mood which sounds more altruistic than inesslike, explains his interest in this field by saying, entists have spent so much time trying to find ways till people that it's time to find ways to save lives."

n late 1957, Airborne soared into the field of outer ce technology. W. E. Fromm, Director of the com- y's Project STAR (Space Technology and Advanced earch), describes his work as "literally blazing a trail the virgin field of space technology, tackling problems er before encountered by man." And even a quick at the unique set of specifications Fromm is required neet indicates that he is doing just that.

n May 1959 AIL was awarded the prime contract for a million dollar electronic reconnaissance system which be developed for the United States Air Force. The nical program areas in this contract include antennas, ivers, air based and ground based computer, recorders, a-red equipment, and complete programs in reliability testing, weapons-systems integration, and logistics. AIL is responsible for the overall management of the program both administratively and technically. The receipt of this important contract is a tribute to AIL's scientific capabilities.

To support all of these varied activities, AIL employs over 2100, about one-third of whom are graduate engineers and scientists. Housed until recently in eight buildings scattered in several Long Island cities, the Research and Engineering Division has recently consolidated its activities into a brand new 157,000 square foot plant at Melville, Long Island.

Advertising

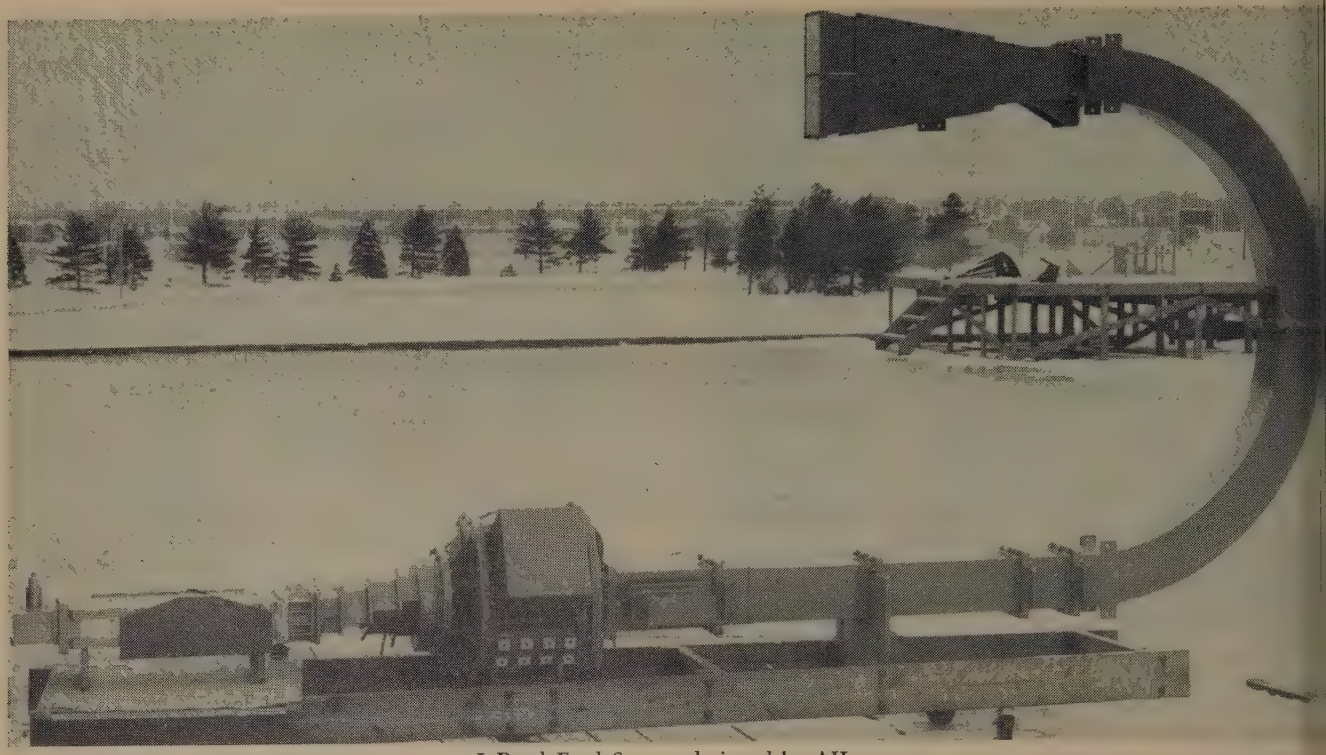
Familiar to virtually every member of the IRE is Airborne's unique series of ads in the Proceedings. The creation of capable Public Relations Director Harold Hechtman and John Dyer, AIL's Vice-President, the series originally appeared in the monthly publication of the IRE's Long Island section. Although Hechtman and Dyer were sure their basic idea was sound, the immediate and overwhelming acceptance of the series came as a surprise even to them. Reasoning that what was successful for a Section of the IRE should be even more successful for the whole Institute, the campaign was shifted to the Proceedings of the IRE where it has appeared monthly ever since.

Instead of describing company products or facilities, each ad is a brief semi-technical discussion prepared by one of the engineering departments. Subject matter ranges from summaries of AIL research projects ("The Problems of Aircraft Collision Prevention," March and April 1958), to those that are intended to be of specific value to the electronic design engineer ("New Techniques in Microwave Receiver Construction," February 1957; "Transformerless Single-Sideband Balanced Modulator," December 1956). But most fascinating are the slightly-off-the-subject items, such as "Backward Waves in Highway Traffic Jams" of January 1957 (which shows one of the reasons for the oscillatory stop-and-go behavior of car flow), and "An Observation on the Detection by the Ear of Microwave Signals," which appeared in October 1956.

The ads earned for AIL the first and only award for advertising the IRE has ever given. But perhaps more surprising is the praise accorded the young company by the advertising profession itself: the unusual approach was highlighted in September 1958 as a possible solution to the problem of promoting a firm like Airborne, by the authoritative Printers' Ink.

MERGER

This combination of a strong Electronic R & D company with a strong production center proved to be just what Cutler-Hammer, the 66-year old control equipment firm, was looking for; and in mid-1958 AIL became an operating division of the older firm. Cutler-Hammer's President Philip Ryan explained the move by noting that in order to maintain his company's market position they needed to branch out strongly into electronics. Neither time nor competition would permit building their own electronics division. Instead, they acquired AIL (on a share for share basis) because as he said they are "technically trained groups of scientists and engineers who have achieved an international reputation for scientific achievements."



L-Band Feed System designed by AIL

The New York Times, July 20, 1958 very aptly described the Cutler-Hammer AIL merger with the following statement:

"An almost classic example of the 1958-model business marriage is afforded by the recent case of Cutler-Hammer, Inc., Milwaukee, and Airborne Instruments Laboratory, Inc., of Mineola, L.I. Here was a big company (Cutler-Hammer) absorbing in total a smaller concern (Airborne). Why?

Cutler-Hammer makes electrical control equipment, engineered systems for steel and other continuous process industries, power relays for aircraft and missiles. Airborne Instruments is engaged in research, development, production and engineering in electronics and related fields, of its total volume about 90 percent consists of defense business. By contrast, Cutler-Hammer derives only 10 percent of its revenues from that source. On the surface, these two companies might appear to have little in common.

But the merger brings together large manufacturing facilities and an international sales organization (Cutler-Hammer) and a highly skilled research group conversant with the latest technologies (Airborne). Airborne can supply basic and practical know-how in electronics and allied fields; Cutler-Hammer can translate that into manufactured products. One likely result: the new, broader company will be in a position to land contracts that neither of the two predecessors could have handled alone.

As a matter of fact this has already happened. New company equals new business equals renewed growth."

THE MERGER THAT WORKED

"One Plus One Equals Three"

Cutler-Hammer's acquisition of AIL has resulted in not one integrated company, nor with two autonomous companies but with a complex of three: — Cutler-Hammer continues to manufacture its standard line of controls, AIL pursues the same lines it did before the merger, and in addition AIL's Industrial Department has joined with C-H's Systems Sales group, forming what can be considere a third organization. Together, using the technical brai power from AIL and the production know-how from C-H they have been able to undertake bigger and more im portant projects than either company would have touche before the merger. Larger control systems, data accumul tion (such as in steel mills), and automatic warehousin are among the new fields the company has been able t enter successfully.

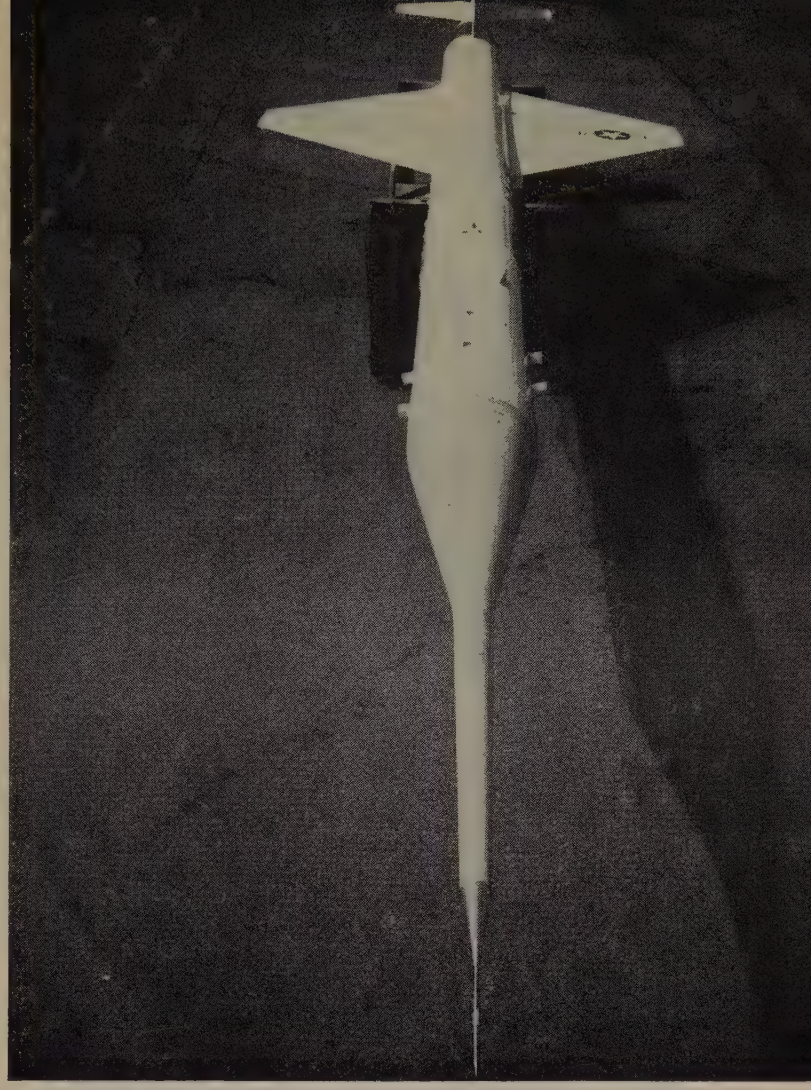
"Obviously all mergers look good when they are made said Philip Ryan, "the proof of a merger is how does it loo a year later. Now that Cutler-Hammer and Airborne hav been married for one year, we say that the merger is goo and looks better than it did at the start."

To point up Mr. Ryan's remark, let us quote brief from the Wall Street Journal of April 14, 1959, reportin on the annual stockholders meeting of Cutler-Hamme Inc. "Net sales advanced about 25% . . . compared t the same period last year, President Philip Ryan reporte The figures represent the combined sales of Cutler-Hamm and Airborne Instruments Laboratory, which Cutler-Ham mer acquired a year ago and now operates as a divisio . . . All of the sales increase occurred in the defen business of Airborne Instruments . . . Cutler-Hamme Ryan noted, has a special stake in the controls it mak for the power industry. Indications are that the contr segment is growing faster than the industry itself, a that the electronic division of the industry is growi more rapidly than any other segment. The Airborne I struments Laboratory fits into the electronic segment. Ry added that with these two segments, — controls and A borne — the company's outlook is very bright, indeed . .

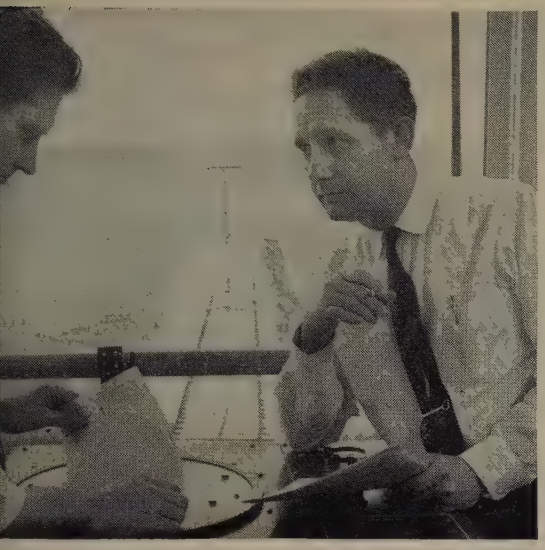
CRYSTAL GAZING

As for Airborne's future, Donald Miller has stated his i tentions in no uncertain terms: "The AIL of tomorro will be a diversified organization with research and d velopment activities counter-balanced by extensive p duction operations."

(right) Lockheed Q-5 target missile features telemetry that registers miss-distance and theoretical hits in testing accuracy of other missiles.



ANTENNA—TELEMETRY



Studying results of antenna pattern measurements — part of the activity of the Space Communications laboratory.

Expanding the Frontiers of Space Technology

Lockheed maintains extensive research capabilities for the development of antennas and telemetering systems and spacecraft applications.

Laboratory studies in antennas and electromagnetic propagation include the application of solid state materials to microwave transmission line components; the design of antennas to survive the rigors of space flight; the effects of space on radio signals and radar detection; and the scattering from missile shapes and space vehicles. Research is also being conducted in the application of ferrites and MASERS; on problems of radio transmission between space vehicles and Earth, re-entry scattering and diffraction by man-made objects and ionized gases; and development of antennas for data link systems between satellites and ground stations.

Telemetering has been brought to a high degree of successful application in the integration of circuits and components into high-performance systems. A completely sub-miniaturized FM-AM system has been developed, along with a complete PAM-FM system characterized by highly efficient band-width utilization, low power consumption and economy of size and weight. This represents a significant achievement in the field of high capacity telemetry.

Scientists and engineers of outstanding talent and inquiring mind are invited to join us in the nation's most interesting and challenging basic research and development programs. Write: Research and Development Staff, Dept. F-22, 962 W. El Camino Real, Sunnyvale, California.

"The organization that contributed most in the past year to the advancement of the art of missiles and astronautics."
NATIONAL MISSILE INDUSTRY CONFERENCE AWARD

Lockheed

MISSILES AND SPACE DIVISION

Weapons Systems Manager for the Navy POLARIS FBM; DISCOVERER SATELLITE; Army KINGFISHER; Air Force Q-5 and X-7

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CAPE CANAVERAL, FLORIDA
ALAMOGORDO, NEW MEXICO • HAWAII

ENGINEERS AND PHYSICISTS R & D ON NEW MICROWAVE DEVICES

Microwave Associates, Inc. invites qualified engineers and physicists to discuss an unusual opportunity to perform R & D work on new microwave devices utilizing ionized media, ferrites and semiconductors. A broad background can be achieved in the interaction of electromagnetic energy with non-linear lossy dielectrics. Here is an opportunity to grasp the advantages of each medium, combine their properties, and develop new devices.

Excellent high power and low power facilities are available for complete study and test of these devices over a wide frequency spectrum — 400 to 70,000 MC.

You are invited to a confidential exploratory discussion of your future with us. Contact Dr. Lawrence Gould for suitable arrangements.

MICROWAVE ASSOCIATES, INC.

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BRowning 2-3000

You'll enjoy living in this suburban town — only 47 minutes from New York City.

Send your resume today — it will be held in the strictest confidence.

Mr. Donald M. Gerber

MANSON

TOP FLIGHT POSITION AVAILABLE FOR

SR. PROJECT ENGINEER

A rewarding present and attractive future awaits the or man we are looking for — especially if you've had sig nificant or closely related experience in the following

HIGH POWER PULSE MODULATOR DESIGN
- For radar and microwave systems as well as tube and components testing.

HIGH VOLTAGE POWER SUPPLY DESIGN
- To meet modern demands for TWT, Klystron, Carcinotron and backward wave oscillator applications.

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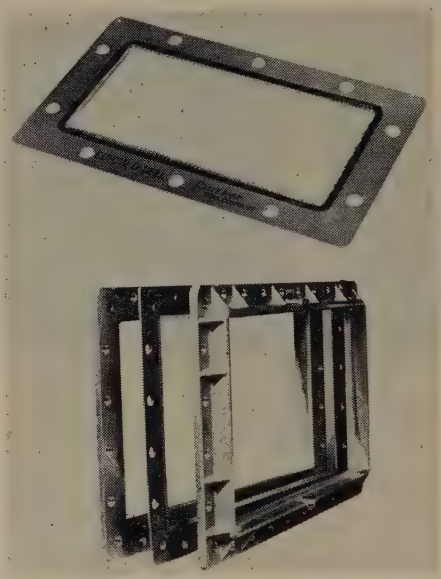
375 Fairfield Ave., Stamford, Conn.
DAvis 5-1391

NEW PRODUCTS

WAVE GUIDE SEALS PROVIDE POSITIVE MECHANICAL SEALING: PREVENT R/F LEAKAGE



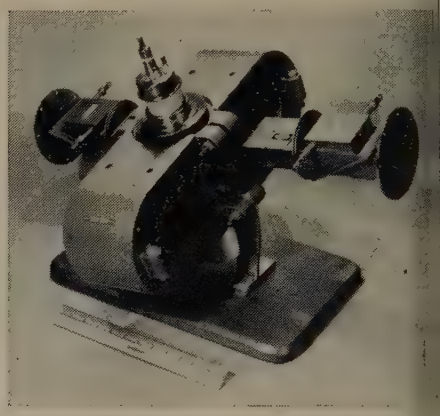
A complete line of seals for WR- series and X-band wave guides, which provide no-leakage fluid sealing, prevent R/F leakage and eliminate burning and/or arcing, has been developed by Parker Seal Company, a Division of Parker-Hannifin Corporation.

Called Electr-O-Seals, the new seals are made to fit EIA (RETMA) standard guides and, in addition to positive sealing, provide savings by making special machining of flanges unnecessary. The inside metal mating edges of the seal are knurled to assure positive electrical contact. They are also reuseable.

A proper mass to void ratio is maintained, which gives controlled confinement of the seal "gland," with metal to metal contact.

CIRCLE READER SERVICE CARD 104

RAYTHEON QK622 AMPLITRON



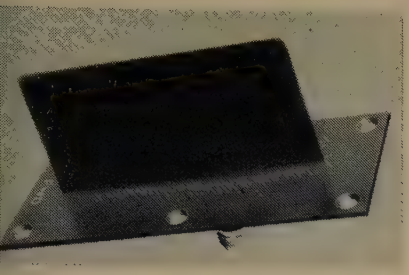
Rated at 3 Mw peak, 15 kW average power output, the QK622 is a new S-band power amplifier stage with wide RF bandwidth. This tube supplies full power over an operating band of 2900 to 3100 Mc at efficiencies greater than 70%. Operating life of more than 1000 hours at rated power output has been demonstrated. Phase stability and pulse stability are excellent. No heater power is required for starting or during operation. General characteristics are as follows:

Peak Power Output (min.)	3 Mw
Average Power Output	15 kW
Pulse Duration	10 μsec
Bandwidth	200 Mc
Duty Cycle	.005
Pulse Voltage	50-55 kv
Peak Anode Current	65 amps
Efficiency	70%
RF Input	475 kw
Weight (with permanent magnet)	125 lbs.

The QK622 can be operated at reduced peak power level to serve as a driver stage. High efficiency is retained at a peak power output of 600 kW and gain of 10 db.

CIRCLE READER SERVICE CARD 105

NEW MODEL L-BAND ELEMETRY BLADE ANTENNA



A new model L-Band Blade An-nna designed for the 1400 Mc tele-etry band is announced by Canoga ivision, Underwood Corp., Van uys, California. The Canoga odel 9955 Blade Antenna is the test model in a series of high per-rmance types which have been de-gned for high speed aircraft and issile applications.

The polarization is perpendicular the mounting surface and the re-lting radiation pattern is circular. he Model 9955 has a maximum SWR of 1.5 over a 25% frequency and, is 3.55" long, extends 1.70" om the skin of the airframe, and eighs 7 ounces.

• • •

IRCLE READER SERVICE CARD 106

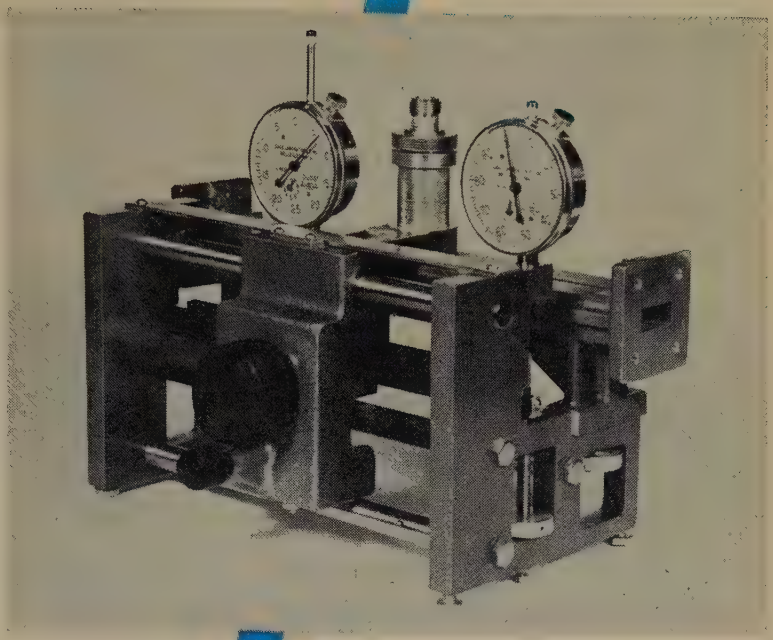
RGANOMATION ASSOCIATES OFFER HIGH-SPEED ANALYTICAL EVAPORATOR

Designed to expedite analyses of nall fractions, the N-EVAP pro-des convenient means for simul-neous evaporation of solvent from samples in 50 ml. Erlenmeyers or 2 samples in test tubes of 24 mm. aximum diameters.

The basic assembly consists of a pport stand, sample holder, gas anifold, and twelve gas injectors ith individual needle valves to con-ol rate of flow. The height of the as injectors can be individually djusted and readily readjusted as aporation proceeds. A small thumb rew permits the entire assembly be secured at the desired height the support stand. The assembly n be freely rotated giving access each sample from the front. A ermostatically controlled water th permits samples to be evap-ated at constant temperature, ad-stable from 35 to 70 degrees C. he equipment can be readily used any laboratory technician.

• • •

RCLE READER SERVICE CARD 107



SAGE

The SAGE-601 Slotted Line Carriage, when used with the proper slotted line sections, provides complete coverage from 2,600 to 40,000 MC. The carriage comes equipped with a coarse and vernier drive and features bottom mounting of slotted sections. All slotted lines have tapered slots for minimum residual VSWR. The Automatic Phase Indicator is available as an attachment.

Pictured above:

SAGE-601	Slotted Line Carriage	$225.00
SAGE-602	Broad Band Probe to Type N Coax	$35.00
SAGE-610	.900 x .400 I.D. Slotted Line Section	$90.00
SAGE-615	Automatic Phase Indicator Attachment	$100.00
		$450.00

Delivery within 30 days of an order.

CIRCLE READER SERVICE CARD 18

SAGE laboratories, inc.

159 LINDEN STREET WELLESLEY 81, MASS.

RESEARCH ENGINEERS

Challenging assignments are presently available for Electronic Engineers at all levels of experience to work on interesting military and industrial projects in the following areas:

Communications Systems - Radio-Radar Systems

Electronic Instrumentation

Electronic Components - Electronic Interference

Microwave and Propagation Studies

Members of our Electrical Engineering Research staff enjoy an exceptional opportunity for personal and professional growth through project assignments carried out in an atmosphere conducive to good research. In addition they receive competitive salaries and benefits which include a generous relocation allowance and up to four weeks paid vacation.

If you are seeking increased responsibility and professional recognition, send a resume of your qualifications to:

A. J. PANERAL

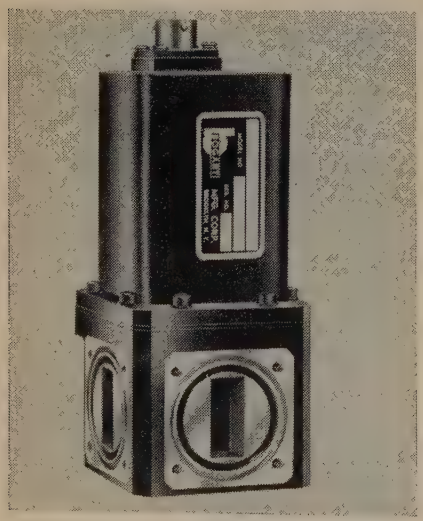
ARMOUR RESEARCH FOUNDATION

of Illinois Institute of Technology

10 West 35th Street · Chicago 16, Illinois

NEW BOGART WAVEGUIDE SWITCH

The Bogart Manufacturing Corporation of Brooklyn, New York announces the development of a new X-Band waveguide switch, model 4438.



The model 4438 is a miniaturized device for RG-51/U waveguide and operates in the frequency range 8500-9600 Mc with greater than 60 db isolation.

The result of a unique design technique, the unit is smaller than switches now available and is relatively inexpensive. A switching time of less than 50 milliseconds coupled with its small size makes the switch ideally suited for modern missile and radar applications.

• • •

CIRCLE READER SERVICE CARD 108

INDUSTRY LITERATURE

CATALOG DESCRIBES INDIANA LOAD ISOLATOR MAGNETS

Catalog No. 20, describing Alnico V permanent magnets for Microwave Load Isolators, has just been released by The Indiana Steel Products Company. The magnets listed in this new catalog are available for immediate shipment from stock.

The new catalog describes the basic sizes and shapes of "C" type magnets available for this important microwave application, as well as information on how experienced Indiana design engineers can help solve load isolator design problems.

• • •

CIRCLE READER SERVICE CARD 110

FXR SHORT FORM CATALOG NOW AVAILABLE

FXR, Inc. is now distributing a new Short Form Catalog which not only contains listings of all components but their prices as well.

Waveguide components, coaxial components, instrumentation and high-power pulse modulators are described and listed separately. Sufficient technical data and illustrations are included for the microwave engineer's basic information. Other details, which include prices, will enable purchasing agents to select the model numbers of wanted equipment and ascertain their costs. The sales representatives throughout the United States and in Canada who may be called upon for additional information and service, are also listed.

CIRCLE READER SERVICE CARD 109

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PROTECTING THE COMPANY'S INVESTMENT IN CREATIVE TALENT

HENRY F. FRAILEY—POWER TUBE OPERATIONS MGR.
WESTINGHOUSE ELECTRIC CORP. — ELECTRONIC TUBE DIVISION

ortly before his discharge, Henry F. Frailey, serving as a deck officer on one of Uncle Sam's destroyer-minesweepers, assisted in e preparation of the Bikini Atoll for the first atomic energy tests in the Pacific. Since then, this energetic young executive has mpleted his chemical engineering requirements at the University of Notre Dame, married and is raising a family of five daughters d two sons, won and completed a one year Sloan Fellowship at MIT for a Master's Degree in Industrial Management and pro-essed to his present position at Westinghouse.

That much information gives a fair description of "Hank" Frailey. The details would point out that he was born and raised in ncaster, Pa., and his four year stint in the U.S. Navy temporarily interrupted his college education. His first two years out of llege were with Sylvania Electric Products, Inc., in product development engineering and the next three years were spent in 'A's Tube Division as a manufacturing engineer.

Mr. Frailey joined the Westinghouse Tube Division in 1951 as a senior engineer and advanced to chief manufacturing engi-er, then factory superintendent in 1955. In 1957 he was appointed Operations Manager responsible for a factory and engineering ility covering 220,000 square feet, employing 600 people and designing and making such products as microwave devices, im-e and pick up tubes, storage tubes, neutron counters, industrial tubes and welding control devices.

The chronological progress of today's outstanding gineer or scientist follows a general pattern. Follow-graduation with the minimum of a Bachelor's De-e, he is employed by an industrial company in either velopment or production activities — development in this sense extends from pure research to the product development area. Approximately five years later, his high performance reveals an inventive and energetic individual with more than the normal endowment of creativeness. Around the tenth year our budding scientist has

filed a number of patents, authored significant technical articles and "points with pride" to his contributions to his company's product availability list. Between the tenth and twentieth year he has established himself in his industry and in professional societies as a top-level creative scientist and most often, has by now acquired a Master's or Doctor's Degree or equivalent.

Unfortunately, too often we find that around the fifteenth year he has been promoted to a position of near-top management and a good portion of his time is taken up by the day-to-day chores of administration, severely limiting, if not eliminating, his time available for technical work. In an honest effort to reward scientific excellence, American Industry places him in the traditional prestige position of management and in so doing, smothers the very abilities that have earned him recognition.

Corporate progress in today's economy is the result of many coordinated functions, not the least of which is technical competence. Certainly, in the Electronics Industry a strong market position in the long run is ultimately dependent on research and development accomplishments. More and more top corporate management personnel are emerging from engineering ranks, but then this is to be expected in this era of high technological advancement. A recent study of the National Science Foundation shows an increase of 400% in the number of research people from 1945 to 1957 (227,000) and a still much larger number of technical people are involved in product development and product engineering. Obviously, not all scientists and engineers can be managers and for the 1 in 8 to 1 in 15 who is selected for management responsibilities, it is important that selection is made weighing business and administrative potential of the individual as well as his demonstrated technical ability. A truly creative man does not come along every day and to smother his inventiveness under the heavy blanket of day-to-day business management pressures is being most wasteful of a valued asset.

To protect the corporate investment in the top scientist, Management must provide a satisfactory "status" position free from administrative responsibilities and one that will be evaluated by all technical employees to be as desirable as a management position. The supervisory requirement of this position should be limited to one of technical direction. Before setting down what I feel are the proper requirements for such a position, let us look briefly at the most common method being used for handling the situation, not too successfully. To recognize achievement, the scientist is promoted to top engineering management and dilution of his inventive skill is reduced by giving him a staff assistant to handle his day-to-day problems in planning and administration. Too often, this results in a division of responsibility and authority and causes confusion p an extra level in the line of communication.

The demand for technical talent, the vigorous recru ing efforts being made for this talent and the mobili of people in today's society, all greatly increase the ne for proper organizational placement of the valuab engineer. I believe the key to establishing a presti position that protects the creative talent is to reali that the top scientist considers his profession to be least as important as the company for which he work The non-management position to be established for t creative scientist should, therefore, satisfy the followi requirements:

1. The position should carry a title which signi cantly describes the man's importance.
2. Compensation should consist of all the particul elements received by management personne profit-sharing, bonus, stock purchases, etc.
3. The major portion of his time should be taken u with technical direction of projects, consultatic and personal experimentation.
4. The top scientist should be given opportunity advise management regarding the technical aspec of policy-making and planning — in market pla ning and product styling this is a necessity.
5. The scientist should be given adequate publicity f his accomplishments using all the media availab but in particular within the professional societi in which he takes active part.
6. He should periodically be exposed to the financi reviews of his company so that he is able to sha with management an understanding as well as feeling of responsibility for the progress of t business.
7. Technical objectives should be clearly defined an reviewed on something like an annual basis. Th expense and capital budgets made available to a tain these objectives should be firmly set, an once approved, the scientist should be allowe full authority in the expenditure of this money.

There are, of course, many other less significant r quirements that are found in the personal relationshi between management and the high-level creative eng neer which I would like to cover by simply saying tha he should be an important member of the "inform organization." One of the distinguishing marks of th creative engineer is the fact that he is being constant sought out for consultation by other technical personne He must make available adequate time to advise thes people.

When your young engineers seek advancement int this position in place of becoming a manager, successfu establishment and recognition of this position will b achieved and your company's investment in creati effort will be perpetuated.

Galileo Meets the Martians

One memorable day in 1633, 5 space ships suddenly materialized in the sunny Italian sky over Pisa and landed directly under the nose of Galileo's telescope. Three creatures alighted from the lead ship and made straight for Galileo.

"Good morning Signor Galilei," they chorused in unison. "We are . . ."

"Don't tell me, let me guess," interrupted the scientist. "The Mars Brothers?"

"In the flesh, more or less," leered the green one in the middle, brandishing a cigar. "I'm Sloucho. Sorry about the accident. We seem to have knocked off a Pisa the Tower."

"Good for the tourist trade," Galileo smiled.

"Now for business," went on Sloucho. "The boys upstairs are fascinated with your radar. They sent us down here to find out how you make it work without Bomac tubes."*

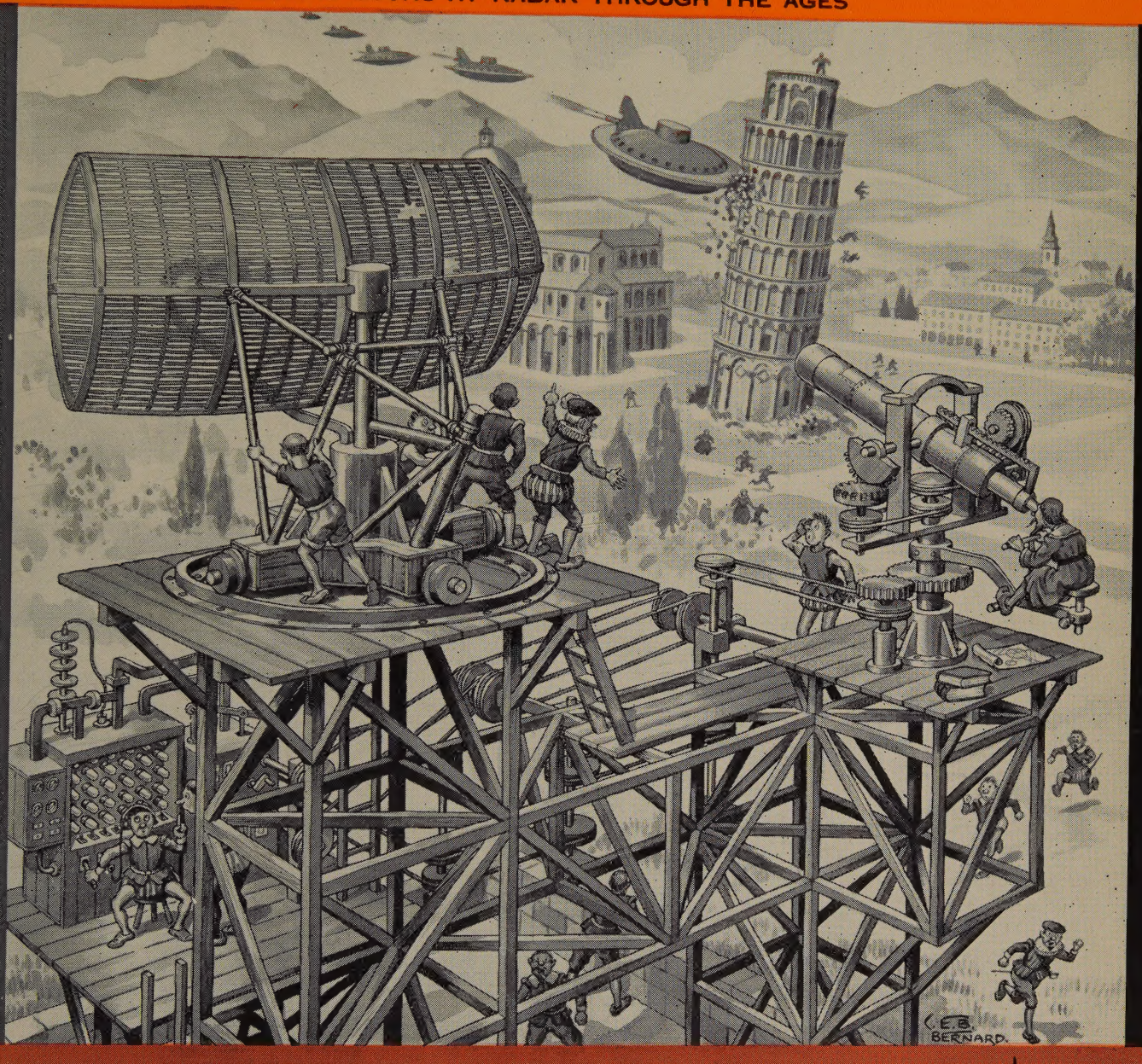
"I'm sorry to say it doesn't work at all," Galileo answered. "Or rather — it didn't, until the instant your ship hit the tower."

Sloucho's cigar was aquiver with excitement. "What happened then?" he asked.

"See for yourself," Galileo said, pointing a bony finger at the radar console. There, blinking crazily, like so many overstimulated lightning bugs, the tubes were actually spelling out a single, sure-enough word.

The word was "TILT."

No. 14 of a series . . . **BOMAC LOOKS AT RADAR THROUGH THE AGES**



* *Bomac makes the finest microwave tubes and components this side of the leaning tower*

WRITE FOR FREE SIX PAGE FOLDER **Bomac LABORATORIES, INC.**

Salem Road, Beverly, Massachusetts

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